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Original articles

ORIGINAL ARTICLES

THE NATURE OF THE ORGANIC NITROGEN COMPOUNDS OF RICE SOILS

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(Received for publication on 13 June 1950)

A CONSIDERABLE amount of work has been done on the nature of the organic nitrogen compounds of soils. The literature on this subject has been reviewed by Waksman [1938], and no attempt will be made to discuss it again in this paper. But a brief summary of the more important results obtained by different workers in this field is given below in order to indicate the present position of the problem.

Nitrogen occurs in soils mostly in organic form ; that present in inorganic form is very small comprising less than five per cent of the total nitrogen and consisting mainly of ammonia and nitrate. A considerable proportion of the organic nitrogen is present as proteins or protein-like bodies. This is apparent from the work of Jodidi [1911, 1912], Kelley and Thompson [1914], Shmook [1914], Potter and Snyder [1915], Lathrop [1916] and Morrow and Gortner [1917]. These workers hydrolysed the nitrogenous complexes of soils by directly boiling the soil with mineral acids and determined the distribution of nitrogen in the hydrolysates. The results showed that amino acids were the main products of hydrolysis. Suzuki [1906-8] actually isolated some amino acids by Fischer's ester method from the acid hydrolysate of a peat.

The proteins present in soils appear to be different from common animal and plant proteins in that the former are much more resistant to microbial decomposition and are not easily extractible by solvents. This has led to the view that soil proteins are largely of microbial origin, which occur in soils, not in a free state, but in the form of complexes with other compounds.

Several protein degradation products were isolated from soils, although proteins as such have not been extracted to any large extent. Walters [1915] separated a mixture of proteoses and peptones from the alkali-extract of soil from which humic acid had been removed by acidification. Schreiner and Shorey [1910] have isolated a number of compounds including arginine and histidine ; the second author [1913] has also isolated lysine and nucleic acid. The presence in soil of leucine and isoleucine was demonstrated by Robinson [1911]. In addition to these compounds,

(*) The work described in this paper was done before the Senior author (P. K. De) left Dacca University in September, 1947.

several others including some purine, pyrimidine and pyridine derivatives have been isolated from soil [Waksman].

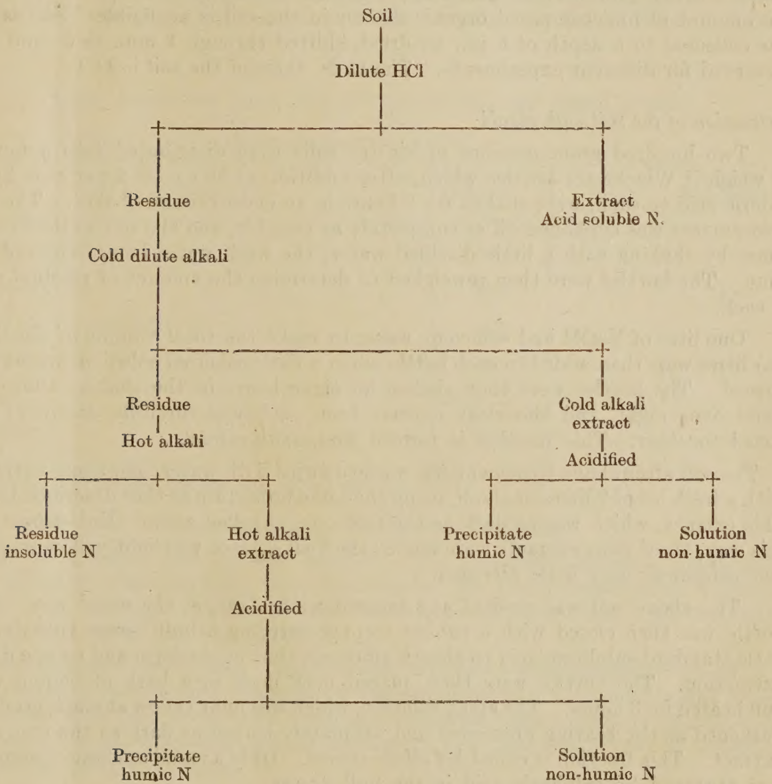
The nitrogen content of humic acid has been of considerable interest. Humic acids obtained from different sources contain varying amounts of nitrogen, and all attempts to obtain a nitrogen-free product have so far failed. From a similarity in the distribution of nitrogen in the hyderolysates of purified humic acids and of typical proteins, Hobson and Page [1932] concluded that the nitrogen in humic acid is present in the form of proteins. The failure of pepsin and trypsin to act on these proteins was explained on the assumption that the manner of association of humic acid and protein is such as largely to protect the latter from the action of proteoclastic enzymes. The same authors [1932] further observed that 30 to 40 per cent of the non-humic nitrogen of Rothamsted soil is present in the form of peptides, with 5 per cent of free amino nitrogen and 12 per cent of ammonia. The non-humic nitrogen-compounds are believed to be incorporated in the humic-clay gel.

The present investigation is concerned with the organic nitrogen compounds of rice soils. As is well known, rice-fields are kept submerged during crop growth, while after harvest and until the next transplantation they are allowed to remain dry and fallow. This practice of maintaining an alternately dry and water-logged conditions has been consistently followed ever since rice was first grown on these lands. Consequently in these soils, the decomposition of the added organic materials and further decomposition of humic matter itself have proceeded under conditions different from those obtaining in normal agricultural soils. It was thought that this difference in treatment might have brought about marked differences in the nature of the organic nitrogen compounds of rice soils.

De and Pain [1936] have examined some Indian rice soils, with regard to the solubility of the organic nitrogen in cold, dilute alkali, and observed that the proportions of alkali-soluble nitrogen in majority of the soils were nearly similar, in spite of the fact that the samples examined were collected from localities widely apart and under different climatic conditions. In the present investigation, attempts were made to ascertain the forms in which organic nitrogen occurs in rice soils. For this purpose, organic matter was fractionated into different parts and the nitrogen compounds in each were characterized as well defined chemical groups or complexes. No attempt has been made to isolate individual compounds from any fraction.

The method of fractionation and the nomenclature employed in this investigation are essentially the same as those used by Hobson and Page in their study of the Rothamsted soils. Briefly, the method consists in a pre-treatment of the soil with dilute hydrochloric acid to liberate humic acid from its combination with bases, followed by several extractions with cold dilute alkali and afterwards one extraction with hot alkali. The alkali extracts are further fractionated by acidification when *humic nitrogen* is precipitated and the *non-humic nitrogen* remains in solution. The

residual soil after hot alkali extraction contains *insoluble nitrogen.* The scheme of fractionation and the nomenclature employed are summarised below.



In this investigation the nitrogen compounds in humic, non-humic and insoluble fractions were examined. Preliminary acid treatment extracted only three per cent of the total nitrogen which was mainly inorganic.

Experimental

Soil sample

The soil sample used in this investigation was collected from the Plot Khoskhana Byde of the Government Agriculture Farm at Dacca. This is an unmanured plot in which rice has been grown for a long time. The field remains under water from June to November when the crop is growing, and dry during the remaining fallow

period. Little growth of grass appears in the field during the fallow season ; this together with the rice roots is the only addition of organic matter which the soil receives every year. These materials, however, are easily decomposable, so that the amount of undecomposed organic matter in the soil is negligible. Soil sample was collected to a depth of 6 in., air-dried, shifted through 1 mm. sieve and then preserved for different experiments. The C. N. ratio of the soil is 11·1.

Extraction of the soil with alkali

Two hundred gram portions of air-dry soils were distributed into a number of weighed Winchester bottles which, after addition of 55 c.c. of 2 per cent hydrochloric acid to each, were shaken for 2 hours in an end-over-end shaker. The clear acid-extract was syphoned off as completely as possible, and the soil washed several times by shaking with a little distilled water, the wash water being removed each time. The bottles were then reweighed to determine the amount of residual water in each.

One litre of NaOH and sufficient water to make the total volume of the liquid two litres were then added to each bottle when a dark-coloured solution was at once formed. The bottles were then shaken for eight hours in the shaker, allowed to stand over night, and the clear extract from each was carefully drawn off and mixed together. This fraction is termed *first alkali-extract.*

The soil after above treatment was washed twice with water, and again extracted with a fresh lot of 2 litres of alkali, using the same procedure as that described before. This extract, which was as dark as the first one, is called *second alkali-extract.* In this way, three more extracts were made ; the final extract was light yellow in colour and contained very little nitrogen.

The above soil was washed and treated with alkali in the usual way. Each bottle was then closed with a rubber stopper carrying a bulb tower containing a little standard sulphuric acid to absorb ammonia that might form and escape during extraction. The bottles were then placed neck deep in a bath of boiling water and heated for 3 hours. The alkali solution, which was light yellow at start, gradually darkened as the heating proceeded and ultimately looked as dark as the first alkali extract. This fraction is called *hot alkali-extract.* Only a small amount of ammonia was absorbed by sulphuric acid in the bulb tower.

The residual soil after hot alkali extraction contained insoluble nitrogen. A large volume of distilled water was added to each bottle, which, after a little shaking, was set aside until the supernatant water became almost clear. This took more than a week. The liquid was removed whereupon the soil was washed several times with water slightly acidified with hydrochloric acid, filtered and finally washed with distilled water until the filtrate showed only slight turbidity with silver nitrate. The soil thus obtained was dried, powdered and preserved for the examination of insoluble nitrogen.

For separation of humic nitrogen, 1,000 c.c. portions of different alkali extracts made above were slowly neutralized by the addition of 60 c.c. of concentrated hydrochloric acid, thus giving a final strength of the acid in the mixture equivalent to

N/10. After 8 hours, standing the precipitates were filtered through a dry filter paper, the filtrate being clear in each case. The filtrates thus obtained were used for the examination of non-humic nitrogen and the precipitates (from first alkali extract only) were collected and preserved for the examination of humic nitrogen.

TABLE I

Total, humic and non-humic nitrogen in different alkali-extracts

(N as per cent of total soil N)

Extracts	Total	Humic	Non-humic
1st alkali extract	39·9	11·0	28·9
2nd alkali extract	16·3	4·7	11·6
3rd, 4th and 5th alkali extracts	4·5	..	..
Hot alkali extract	14·8	2·7	12·1
Total	75·5	18·4*	52·6*

*Amounts in 3rd, 4th and 5th extracts not included

EXAMINATION OF NON-HUMIC NITROGEN.

(*a*) *Precipitation with different reagents.* The non-humic nitrogen compounds from different alkali-extracts were fractionated by precipitation with different reagents, the nitrogen content of each fraction being determined. The methods of treatment used were as follows:

Neutralization precipitate. The non-humicfractions were neutralized by adding slight excess of caustic soda, followed by dilute hydrochloric acid until litmus paper just turned pink (*pH* 4·8). The precipitates formed were removed; the filtrates were used for phosphotungstic acid treatment and for the study of nitrogen distribution after hydrolysis.

Waksman [1926] gave this fraction the name β fraction while Hobson and Page preferred to call it 'neutralization precipitate'. The latter nomenclature is retained in this paper.

Basic lead acetate. This treatment was applied to non-humic fraction obtained by acidifying the alkali-extract with acetic acid. The acid solution was slowly neutralized by caustic soda and then acidified by acetic acid to a *pH* 5·9. The neutralization precipitate was removed, and the filtrate therefrom was treated with slight excess of basic lead acetate solution. The precipitates formed were filtered; the filtrate, after being freed from excess of lead by means of potassium oxalate, was submitted to phosphotungstic acid treatment.

Phosphotungstic acid. To the filtrates from the above two treatments was added sulphuric acid to a concentration of 5 per cent, followed by phosphotungstic acid solution in slight excess. The precipitates formed were removed after 48 hours.

TABLE II

Percentage of non-humic nitrogen precipitated by different treatments

Non-humic fractions from	Neutralization precipitate	Phosphotungstic acid	Basic lead acetate
1st alkali-extract	13·7	45·9	..
2nd alkali-extract	11·3	34·0	..
Hot alkali-extract	25·0	15·4	..
1st alkali-extract*	12·4	13·3	40·0

*Acetic acid used for separation of humic matter

A few days after the above experiment was over, it was noticed that a stored sample of a non-humic fraction, which was quite clear when made and used in the above experiment, became distinctly turbid on standing. This turbid fraction, when examined as above, gave results different from those of the original clear one. The latter contained a much higher percentage of nitrogen precipitable with phosphotungstic acid than that with neutralization precipitate, but the reverse was the case with the former. Similar results were also shown by a stored sample of the first alkali-extract, as illustrated below.

—	Per cent of non-humic N in	
	Neutralization precipitate	Phosphotungstic acid
Alkali-extract (fresh)	13·7	45·9
Alkali-extract (stored)	40·2	13·2

The above observation suggests that long exposure to acid and alkali probably brings about some changes in the solution resulting in a transfer of a part of nitrogen from the phosphotungstic acid to the neutralization precipitate fraction. To test this view further, a fresh lot of alkali-extract was made ; portions of it were removed at intervals from which humic nitrogen was separated as usual by hydrochloric acid, and the resulting non-humic fractions were analysed for total nitrogen, for nitrogen in the neutralization and in the phosphotungstic acid precipitates and for inorganic residue in the neutralization precipitate—the last being obtained by igniting to constant weight the precipitates obtained from a known volume. Total nitrogen remained constant for samples made on different dates. Others are shown in Table III.

TABLE III

Effect of exposure to alkali on the precipitation of the non-humic N

Duration of exposure	Per cent of non-humic N			Inorganic residue in neutralization precipitate*
	Neutralization precipitate (*a*)	Phosphotungstic acid (*b*)	Total (*a*+*b*)	
				mg.
1 day	14	44	58	·34
7 days	36	17	53	·62
14 days	42	12	54	·64
28 days	46	12	58	·82

*Obtained from 400 c.c. of the solution

The results show that with the age of the alkali-extract, the nitrogen contents of the phosphotungstic acid fraction gradually diminished, but that of the neutralization precipitate simultaneously increased, the total nitrogen contents of the two fractions, however, remaining practically the same throughout. This would appear to suggest that under the influence of alkali the nitrogen compounds of the first fraction are converted to forms belonging to the second. This view, however, does not receive much support from the observation made in a subsequent experiment that about 77 per cent of the nitrogen in the neutralization precipitate is also precipitated by phosphotungstic acid, showing thereby that the nature of the nitrogen compounds in the two fractions is essentially the same. A more probable explanation is that the nitrogen in the neutralization precipitate is an adsorption product being held up by the inorganic substances, so that with an increase in the amount of the latter, there is also an increase in the adsorption of nitrogen from the surrounding solution.

(*b*) *Acid hydrolysis of non-humic nitrogen.* In order to obtain further knowledge of the nature of the non-humic nitrogen compounds, the filtrate obtained after separation of the neutralization precipitate in the above experiments was hydrolysed by boiling with hydrochloric acid and the distribution of nitrogen in the hydrolysates was studied according to Van Slyke's method of protein analysis (1911-12, 1915). The details of the procedure were as follows:

The solid residue obtained after slow evaporation of 800 c.c. of the filtrate over a water bath was hydrolysed by boiling under reflux with 100 c.c. of 21 per cent hydrochloric acid for 48 hours. During hydrolysis the solution became dark with separation of a black precipitate. The precipitate was filtered, washed with water and analysed for total nitrogen (Humin I—N). The filtrate was made to a known

volume (250 c.c.), of which a portion (100 c.c.) was distilled *in vacuo* to remove hydrochloric acid; when the distillation was nearly complete, a little water was added to the residue, and the process repeated until the distillate showed faint test of acidity. The semi-solid residue obtained after above process was dissolved in water and the solution made up to 100 c.c. Ammonia in this solution was estimated by distilling *in vacuo* two 25 c.c. portions mixed with an equal volume of absolute alcohol and one gram of ignited MgO, the evolved ammonia being absorbed in N/50 H_2SO_4 and estimated by back titration. The MgO residue was filtered, washed with water and the filter paper containing the solid residue was analysed for total nitrogen (Humin II—N). The filtrates from duplicate ammonia determination were mixed up and concentrated *in vacuo* to a small volume; two 10 c.c portions of this solution were used for determination of amino nitrogen by Van Slyke's macro method. The remaining nitrogen, obtained by difference, was taken as non-amino nitrogen. Ammonia and amino nitrogen were also determined in a portion of the unhydrolysed filtrate using the same procedure as described above—the increase after hydrolysis representing amide and peptide nitrogen respectively. The results are given in Table IV.

TABLE IV

Nitrogen distribution in the acid hydrolysates of the non-humic fractions of different alkali extracts

(N as per cent of total non-humic N)

	Non-humic nitrogen from		
	1st alkali extract	2nd alkali extract	Hot alkali extract
Humin IN	4·6	6·6	14·2
Humin II ,,	5·8	12·7	6·5
Ammonia ,,	11·6	21·3	10·9
Amino ,,	6·3	12·0	21·7
Amide ,,	9·3	8·7	14·3
Peptide ,,	17·8	11·3	5·4
Non-amino ,,	30·8	16·0	1·9

As will be seen in Table IV, the nitrogen distribution figures of the three non-humic fractions are not similar, showing that the composition of the fractions was different. Such difference in composition, however, is not altogether unexpected because soil organic matter is a highly heterogenous mixture of which different fractions might have been acted on by successive alkali extractions.

The presence of proteins and their derivatives in all the fractions has already been demonstrated by precipitation with phosphotungstic acid and basic lead acetate (Table II). Increase in amino nitrogen after hydrolysis supports this conclusion. The compounds appear to be present in some simple polypeptide form, as there was no precipitation when the solution containing them was treated with trichloroacetic acid.

All the three fractions contained a large quantity of ammonia and amino nitrogen. Ammonia occurs in soil either in a free state or in exchangeable form. Both these forms must have been removed by preliminary acid treatment of the soil. Ammonia in the non-humic fraction thus appears to be a hydrolysis product formed during alkali extraction. The same is perhaps true for free amino nitrogen.

An increase in ammonia after hydrolysis is an evidence of the presence of amide. It was, however, thought that prolonged boiling with 21 per cent hydrochloric acid, specially in presence of small quantities of inorganic materials like $FeCl_3$ etc., might have brought about partial oxidation of the amino compounds so that the ammonia formed is in reality an oxidation and not a hydrolysis product. To test this possibility, two portions of the same solution were hydrolysed, one by boiling with 21 per cent hydrochloric acid for 48 hours and the other by 5 per cent acid for 3 hours—the latter being the standard procedure for estimation of amide in plant bodies [Chibnall, 1939]. The amounts of ammonia and amino nitrogen formed under the two conditions are as follows :

—	At start	After hydrolysis with	
		5 per cent acid	21 per cent acid
Ammonia N (mg.)	4·5	7·8	7·9
Amino N (mg.)	2·7	3·9	9·0

Hydrolysis with 5 per cent acid produced as much ammonia as with 21 per cent, although the amino nitrogen formed under the latter treatment was considerably greater than under the former. If ammonia is really an oxidation product of amino compounds, then one would expect it to be formed in much greater amount with 21 per cent acid because of the production of more amino nitrogen in this case. It will be further seen in a later experiment that the non-humic nitrogen compounds precipitated by phosphotungstic acid, which were apparently free from inorganic substances like ferric chloride, etc., gave considerable amount of ammonia on being treated with hydrochloric acid. From these observations it is reasonable to conclude that the increase in ammonia, as observed in Table IV, is the result of hydrolysis.

The question now arises what is the nature of the compounds that gave ammonia on hydrolysis. A negative murexide test indicated the absence of uric acid derivatives in the extract. Nothing therefore came from this source. The protein derivatives present have obviously contributed some ammonia as a result of hydrolysis

of amide linkages. It will, however, be seen that the proportion of amide to peptide nitrogen (increase in amino nitrogen after hydrolysis) in results in Table IV is much greater than in hydrolysates of common proteins, as illustrated below :

———	Amide	Basic	Mono-amino	Non-amino
Gliadin	25·5	13·05	52·5	8·6
Edestin	10·18	39·2	48·8	1·7
Fibrin	8·6	32·3	56·3	2·8
Hemoglobin	5·44	32·5	59·1	3·0

The above fact suggests two possibilities—(1) In the non-humin fractions there are compounds, other than protein derivatives, capable of yielding ammonia on hydrolysis, (2) The protein derivatives of non-humin fractions are richer in amide contents than ordinary proteins. The latter view was held by some of the early workers notably Lathrop, Jodidi, Kelley and Thompson, and Potter and Snyder, who have found that when the nitrogenous compounds obtained on acid hydrolysis of humus in soils and in peats are compared with those found on hydrolysis of animal and vegetable proteins, considerably higher concentrations of amide nitrogen are found in the former than in the latter. This phenomenon was explained on the assumption that the humus proteins are richer in amide content than vegetable and animal proteins. Such an assumption, however, is hardly justifiable in view of the fact that the bacterial proteins, which are supposed to be the main sources of humus protein, have themselves a low concentration of amide nitrogen as shown below. It will be more reasonable to suppose that amide comes not exclusively from proteins, but from other sources too.

Nitrogen distribution figures for some bacterial proteins

——	Azotobacter [Omelianski and Sieber, 1913]	Defatted tubercle bacilli [Thomson and Brown, 1922]	Yeast [Thomas and Kolodziejskas, 1913]	Rhizobium *Trifolii* [Wilson 1940]
Humin N	3·65	4·11	4·02	4·57
Amide N	9·9	11·83	6·86	12·2
Diamino N	26·39	27·0	26·67	22·4
Monoamino N	60·0	47·39	60·39	67·8

An examination of the results of hot extract in Table IV clearly shows that amide nitrogen may be derived from sources other than proteins. The percentage

of amide and peptide nitrogen in this fraction is 14·3 and 5·4 respectively. From 60—80 per cent of total nitrogen of protein is generally found as amino nitrogen after hydrolysis. Calculated on this basis, the amount of protein derivative in the hot extract will be 6·9 -9 per cent, which obviously cannot give rise to 14·3 per cent of amide nitrogen. Clearly the excess of amide came from an unidentified source. The fact that hydrolysis takes place after such a mild treatment as boiling with 5 per cent acid for 3 hours suggests that the compounds involved are probably some simple amides.

An examination of the nature of the compounds in the phosphotungstic acid and in the neutralization precipitates was next undertaken. The phosphotungstic acid precipitates obtained from a large volume of the non-humic fraction of the first alkali extract (Table II) were dissolved in slight excess of caustic soda followed by treatment with barium chloride solution. The precipitates of barium phosphotungstate, which retained 39·2 per cent of N in the precipitate, were filtered and the filtrate, after removal of excess of barium by treatment with requisite amount of sulphuric acid, was concentrated *in vacuo*, hydrolysed and the nitrogen distribution in the hydrolysate studied as before.

For examination of neutralization precipitate, it was first dissolved in 5 per cent sulphuric acid followed by treatment with phosphotungstic acid in slight excess. The precipitates formed, which brought down 76·7 per cent of the total nitrogen in the neutralization precipitate, were filtered and examined as above. In this case, barium phosphotungstate retained 61·1 per cent of the nitrogen precipitated by phosphotungstic acid. The results are given in Table V.

TABLE V

Distribution of nitrogen in the hydrolysates of phosphotungstic acid precipitate (Calculated on nitrogen in the filtrate from barium phosphotung state) phosphotungstic acid precipitate from

——	Neutralization precipitate	Filtrate from neutralization precipitate	
	Per cent of total N	Per cent of total N	Per cent of total non-humic N
Humin I—N	6·1	4·0	1·2
Humin II—N	12·2	20·8	5·9
Amino—N	20·6	14·1	4·0
Amide—N	42·7	31·3	8·8
Peptide—N	19·8	21·9	6·3

A reference to results in columns 2 and 3 of Table V shows that although the nitrogen distribution figure of the two hydrolysates are somewhat different, yet there is a marked resemblance between them in that both contain a large amount

of amide nitrogen. It will be further seen from a comparison of the figures in the last column of Table V with those in column 2 of Table IV that out of a total amide content of 9·3 per cent in the non-humic fraction, 8·8 per cent was recovered in barium phosphostungstate filtrate. Peptide nitrogen recovered, on the other hand was only a little over one-third of what was orginally present. If the amides were parts of protein derivatives only, then a loss of the latter would have been attended with a corresponding loss of the former. The present observation, while supporting the conclusion already arrived at that a good deal of amide nitrogen is of non-protein origin, further shows that these amides are basic in nature, precipitable by phosphotungstic acid and nonadsorbable by barium phosphotungstate.

Regarding the nature of the nitrogen compounds in the neutralization precipitate, about 70 per cent of this nitrogen has been precipitated by phosphotungstic acid. Nitrogen distribution figures show that these compounds are not essentially different from those precipitated from neutralization precipitate filtrate, although the former are more susceptible to adsorption by barium phosphotungstate than the latter.

Examination of humic nitrogen

The precipitates of humic matter collected from different experiments were mixed up, powdered and then dissolved in dilute caustic soda. The alkali solution was centrifuged and the clear supernatant extract taken out and precipitated by excess of hydrochloric acid. The supernatant clear solution was decanted off and the precipitate washed once with water. It was redissolved in alkali and re-precipitated, the supernatant water being removed as before. This process was repeated thrice. The precipitate from the last treatment was filtered, washed several times with water and finally with alcohol. The purified humic acid thus obtained was dried in a desiccator.

Hydrolysis of humic acid

The purified humic acid (1·014 gm.) was dissolved in 50 c.c. N/2 NaOH solution in Kjeldahl flask ; the solution was then neutralized with N/2 HCl when humic acid was obtained as very fine precipitate. The object of this operation was to obtain a better contact of humic acid with the hydrochloric acid during hydrolysis. Sufficient concentrated hydrochloric acid was then added to make the final strength equivalent to 21 per cent and the mixture boiled under reflux over a sand bath for 48 hours. The distribution of nitrogen in the hydrolysate was studied as before.

The results show that about 50 per cent of the total nitrogen of the humic acid has appeared as amino nitrogen after hydrolysis, which is almost a certain proof that the greater part of the nitrogen in the humic acid is in some polypeptide form. The protein nature of the nitrogen in humic acid has been established by Hobson and Page, and Waksman and Aiyer [1932].

It was thought interesting to compare the nitrogen distribution figures obtained in this experiment with those obtained by Hobson and Page for a sample of humic acid prepared from Rothamsted soil in order to see how far the humic acids formed

under different soil conditions vary in composition. The soil sample used by these workers was collected from Barnfield Plot 1 C, which received 14 tons of dung annually since 1856, plus 2000 lb. of rape cake since 1861 and is under permanent roots since 1856. A comparison of the figures (Table VI) shows that the nitrogen distribution of the two samples are not very different, showing that humic acids formed under widely different conditions are essentially the same.

TABLE VI

Nitrogen distribution values for humic acid from (a) *rice soil* (*Dacca*) *and* (b) *Rothamsted soils*

—	Humic acid from			
	Rice soil		Rothamsted soil	
	Percentage of total N	Percentage of soluble N	Percentage of total N	Percentage of soluble N
Soluble N	87·85	100	82·5	100
Humin I N	11·8	10·0	17·5	7·6
Humin II N	8·8		6·3	
Amide N	18·0	20·5	15·7	19·0
Amino N	46·7	53·1	48·7	59·0
Non-amino N	14·4	16·4	12·6	15·3

EXAMINATION OF INSOLUBLE NITROGEN

For examination of insoluble nitrogen, 200 gm. of residual soil after hot alkali extraction were hydrolysed by boiling with 200 c.c. of 21 per cent hydrochloric acid for 48 hours. The distribution of nitrogen in the hydrolysate is given in Table VII.

TABLE VII

Distribution of N in the hydrolysate of the insoluble fraction of the organic matter

—	Percentage of total N	Percentage of soluble N
Soluble N	85·5	100
Humin I N	14·4	..
Humin II N	10·9	13·8
Amide N	44·4	51·7
Peptide N	20·5	24·2
Non-amino N	8·9	10·3

The above soil (200 gm.) was heated in a water bath with 200 c.c. of 20 per cent caustic soda solution. The alkali solution, which was almost colourless in the beginning, gradually became dark as the heating proceeded and ultimately became as deep as the first cold alkali-extract. This experiment indicates that the insoluble fraction of soil organic matter probably contains humic acid in anhydride form. But that the whole of it is not humic acid anhydride is shown by a comparison of the nitrogen distribution figures of the humic acid (Table VI) and of the insoluble fraction (Table VII). In the latter case, there is a great preponderance of amide nitrogen and much less amino nitrogen, while reverse is true in the case of humic acid. However, the results obtained leave no doubt that a considerable portion of the insoluble fraction consists of amides, though further characterisation of these compounds is not possible on account of their insolubility in all solvents. Hence, as regards the insoluble fraction the only thing that can be said on the basis of experimental facts is that it consists of some amido or imido compounds associated with humic acid anhydride.

It will be seen that 85·5 per cent of the total nitrogen in the alkali-extracted soil has been made soluble by boiling with HCl. The remaining 14·5 per cent i.e. 3·1 per cent of total soil N either represents a different fraction not hydrolysable by hydrochloric acid or it is merely the Humin I-N formed during hydrolysis of the insoluble nitrogen compounds.

The residual soil after hydrolysis was greyish in colour. It contained very little organic matter (carbon ·00427 per cent) and was not examined further.

Summary

The nature of the organic nitrogen compounds of a rice soil of the Government Agricultural Farm at Dacca was studied.

The organic nitrogen was fractionated firstly by treating the soil with dilute hydrochloric acid, followed by five successive extractions with cold dilute alkali and afterwards once with hot alkali. The first three cold extracts and the hot extract were separated into humic and non-humic fractions by acidification when the former was precipitated and the latter remained in solution.

Each of the non-humic fractions was further fractionated by precipitation with different reagents. It was found that there is an inverse relationship between the nitrogen in the neutralization precipitate (precipitate formed on neutralizing the acid solution) and that brought down by phosphotungstic acid from the filtrate therefrom ; with the age of the alkali extract, there is a progressive increase of the former with a simultaneous decrease of the latter, the total nitrogen content of the two fractions, however, remaining practically constant.

Hydrolysis with boiling hydrochloric acid and a study of the distribution of the nitrogen in the hydrolysates have shown the occurrence of the following compounds in the non-humic fraction—ammonia, free amino compounds, amide, protein derivatives and non-amino compounds. There is evidence that a considerable

portion of amide is of non-protein origin, and is basic in nature and precipitable by phosphotungstic acid.

The nitrogen in humic fraction was found to be of protein nature. Hydrolysis of purified humic acid obtained from rice soil showed that it is similar to one obtained from Rothamsted soil.

The alkali insoluble nitrogen compounds were hydrolysed by boiling with hydrochloric acid which brought about 85 per cent of the insoluble nitrogen in solution. The distribution of nitrogen in the hydrolysate showed that about 50 per cent of the insoluble nitrogen is in the form of amide. Humic acid is present in this fraction not as free acid but as anhydride.

REFERENCES

Chibnall, A. C., (1939). Protein metabolism in the plant. Yale University Press, *New Haven*, 182

De, P. K., and Pain, A. K., (1936). The organic nitrogen of paddy soils. I. Distribution of 'humic' and 'non-humic' nitrogen in organic matter. *Indian J. agric. Sci.* **6**, 1081-1086

Hobson, R. P., and Page, H. J. (1932). Studies on the carbon and nitrogen cycles in the soil, VII. The nature of the organic nitrogen compounds of the soil : 'humic' nitrogen. *J. agric. Sci.* **22**, 497-515

——————— (1932). Studies on the carbon and nitrogen cycles in the soil VIII. The nature of the organic nitrogen compounds of the soil : 'non-humic' nitrogen. *J. agric. Sci.* **22**, 516-526

Jhonson, T. B., and Brown E. B. (1922). *J. Biol. Chem.* **54**, 731-737 Quoted in *Physiology and Biochemistry of Bacteria* by R. L. Buchanan and E. I. Fulmer, I, 84

Jodidi, S. L. (1911). The chemical nature of the organic nitrogen in the soil. *J. Amer. Chem. Soc.* **33**, 1226-1241

——————— (1912). The chemical nature of the organic nitrogen in the soil. *J. Amer. Chem. Soc.* **34**, 94-99

Kelley, W. P., and Thompson, A. R. (1914). The organic nitrogen of Hawaiian soils. *Hawai. Agr. Expt. Sta. Bull* 33

——————— (1914). The organic nitrogen of Hawaiian soils, III. The nitrogen of humus. *J. Amer. Chem. Soc.* **36**, 438-444

Lathrop, E. C., (1916). Protein decomposition in soils. *Soil. Sci.* **I**, 509-532

Morrow, C. A., and Gortner, R. A. (1917). The organic matter of the soil. A study of the nitrogen distribution in different soil types. *Soil Sci.* 3, 297-331

Omelianski, W. L., and Sieber, N. O., (1913). *Ztschr. b. Physiol. Chem.* **88**, 445-459.

Potter, R. S. and Snyder, R. S. (1915). Amino acid nitrogen of soil and the chemical groups of amino acid in the hydrolysed soil and their humic acids. *J. Amer. Chem. Soc.* **37**, 2219-2227

Robinson, C. S. (1911). Two compounds isolated from peat soils. *J. Amer. Chem. Soc.* **33** 564-568

Schreiner, O. and Shorey, E. C. (1910). Chemical nature of soil organic matter. *U. S. Dept. Agr. Bur. Soils, Bull.* 74

——————— (1910). The presence of arginine and histidine in soils. *J, Biol, Chem,* **8**, 381-384

Schreiner, O. and Shorey, E. C. (1910). Pyrimidine derivatives and purine bases in soils. *J. Biol. Chem.* **8**, 385-393

Shmook, A. (1914). Some data pertaining to the forms of nitrogen in soil. *Zhur. Opit. Agron.* **15**, 139-153

Shorey, E. C. (1913). Some organic soil constituents. *U. S. Dept. Agr. Bur. Soil. Bull.* 88

Suzuki, S. (1906-1908). Studies on humus formation. *Bull. Coll. Agr. Tokyo* **7**, 513-529

Thomas, P and Kolodziejska, S. (1913). *Compt. rend. Acad. Sci.* 157, 243-245

Van Slyke, D. D. (1911-12). The analysis of protein by determination of the chemical groups characteristic of the different amino acids. *J. Biol. Chem.* **10**, 15-55

——————— (1915). Improvements in the Method of Analysis of protein by determination of the chemical groups characteristic of the different amino acids. *J. Biol. Chem.* **22**, 281-285

Walters, E. H. (1915). The presence of proteoses and peptones in soils. *J. Ind. Eng. Chem.* **7**, 860-863

Waksman, S. A., (1926). The origin and nature of the soil organic matter or soil humus. *Soil Sci.* **22**, 123-162

——————— (1938). ' Humus ', London, Ballicre, Findall and Cox

Waksman, S. A. and Iyer, K. R. N. (1932). Synthesis of a humus-nucleus, and important constituent of humus in soil peats and composts. *Soil. Sci.* **34**, 43-70, 71-80

Wilson, P. W., (1940). The Biochemistry of Symbiotic Nitrogen fixation (Wisconsin)

TRACE ELEMENTS IN SOME INDIAN GRASSES, FORAGE CROPS, CONCENTRATES, AND MINERAL SUPPLEMENTS

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LATELY certain wasting diseases in animals have been attributed to deficiencies of cobalt and copper in their feed [Russell, 1944 and Stiles, 1946]. Thus the diseases known as 'Bush sickness', 'Morton Mains disease', 'Mairoa Dopiness' in New Zealand, 'Enzootic Marasmus' in Australia and 'Pining' in the United Kingdom have been attributed to a deficiency of cobalt; 'Coast disease' in Australia, 'Salt sick' in Florida, U. S. A. to a dual deficiency of cobalt and copper and 'Swayback' and 'Scouring disease' on 'Teart' pastures in U. K., 'Enzootic Ataxia', 'Falling disease' in Australia and 'Licking sickness' in Holland to a deficiency of copper. In Canada though such diseases are not normally met with, Bowstead *et al.* [1939 and 1942] were able to create diseased conditions similar to cobalt deficiency in sheep by feeding non-leguminous hays of low cobalt content. Investigations have failed so far to show any definite relationship between the contents of these elements in soils with their concentrations in plants; instead a definite relationship has been established between the concentrations of the element in forages and the incidence of the disease in animals feeding on them. Feeds have been classified as deficient and sound depending on their contents of cobalt and copper in the dry matter. Thus pasture containing $<0{\cdot}07$ p.p.m. Co for sheep and $<0{\cdot}04$ p.p.m. Co and $<3{\cdot}5$ p.p.m. Cu for both sheep and cattle are considered deficient [Russell, 1944]. In studies of the occurrence of nutritional disease in animals therefore, it has been the custom to examine their feeds or forages from both healthy and deficient areas. Beeson [1947] found 0·05-0·14 p.p.m. Co and 4·5-21·1 p.p.m. Cu in some of the common American grasses grown in pot culture under identical conditions. Little work, however, has so far been published in India.

The object of this investigation was, therefore, to assess the relative quantities of cobalt and copper in a number of promising Indian grasses grown under uniform conditions as also some other forage crops, concentrates, and mineral feeds usually fed to cattle.

Sixteen grass samples at three different stages of growth from Indian Agricultural Research Institute grass nursery raised under uniform conditions with two maunds of ammonium sulphate per acre per year, five forage crops, nine concentrates and three mineral supplements and one mineral mixture were analyzed for cobalt and copper. The grass and forage crop samples were dried at 70°C. for 72 hours and cut into small pieces with steel shears to avoid contamination [Hood, Parks and Hurtz, 1944]. The other samples came in a ground condition ready for analysis. Cobalt has been estimated by the nitroso-R-salt method [Sandell, 1944] after wet ashing of the material with nitric-sulphuric-perchloric acids. The method has been found suitable for estimation of cobalt in grasses in the range of

0·05γ to 20γ with an accuracy of ± 5 to 10 per cent. It has been found, however, that both dry ashing at 500°C. and wet ashing give almost identical results indicating that cobalt is not lost during dry ashing at the above temperature. The carbamate method [Holmes, 1945] which is in use in this laboratory has been utilized for the estimation of copper. A Lumetron Photo-electric Colorimeter (model 402 E) was used for obtaining transmission readings. The results are given in Tables I and II. The chemical composition of some of these grasses have been reported by Mirchandani and Dabadghao [1949].

TABLE I

Cobalt and copper content of grasses at different stages of growth from I. A. R.I grass nursery*

Species	Cobalt p.p.m. D.M.				Copper p.p.m. D.M.			
	Young	Pre flowering	Flowering	Classification according to Russell [1944]	Young	Pre flowering	Flowering	Classification according to Russell [1944]
Dichanthium annulatum.	0·30	0·10	0·04	D	10·2	9·0	7·0	S
	0·30	0·09	0·06					
Amphilophis odorata	0·33	0·12	0·09	S	8·3	4·4	4·2	D
Iseilema laxum	0·55	0·12	0·12	S	11·7	8·2	4·4	D
	0·60	0·12	0·12		10·6			
Themeda tremula	0·20	0·07	..	..	15·3	4·8	..	..
Amphilophis glabra	0·22	0·13	0·17	S	9·1	9·0	8·6	S
	0·30	0·14	0·15					
Pennisetum orientale	0·33	0·12	0·05	D	9·8	7·5	7·4	S
	0·37				9·4			
Panicum repens	0·36	0·06	0·05	D	10·1	9·7	6·2	S
	0·33	0·07					5·9	
Chrysopogon montanus	0·35	0·09	0·07	M	10·5	4·5	4·1	D
Schima nervosum	0·38	0·09	0·07	M	8·8	5·4	4·5	D
Heteropogen contortus.	0·24	0·12	0·12	S	10·2	7·2	6·0	M
	0·25	0·09			12·0		5·5	
Dubgrass	0·10	..	..	..	9·2	..	..	..
Themeda anathera	..	..	0·10	S	..	..	4·0	D
Cenchrus setigerus	..	..	0·11	S	..	..	7·1	S
Arundinella nepalensis	..	..	0·13	S	..	..	8·2	S
Mnesithea laevia	..	..	0·09	S	..	..	5·5	M
Digitaria marginata	..	..	0·25	S	..	..	8·5	S

S = sound; M = marginal; D = deficient

* Indian Agricultural Research Institute

TABLE II

Cobalt and copper content of forage crops, concentrates, and mineral supplements fed to I. A. R. I. Dairy cattle

Feeds	Co. p.p.m. D.M.	Cu. p.p.m. D.M.
a. Forage crops		
Napier grass (*Pennisetum purpureum*)	0·29 0·30	14·3 14·2
Maize plants (*Zea mays*)	0·28	6·1
Berseem (*Trifoliom alexandrinum*)	1·06	10·48
Cowpeas (*Vigna cafjang*)	0·60	8·4
Bhusa (*Jai*)	0·25 0·24	4·9 5·0
b. Concentrate —		
Maize	0·04	3·8
Barley	0·15	4·1
Oats	0·10	5·3
Peas	0·25	8·5
Gram	0·42	7·1
Linseed cake	0·83 0·81	22·3 22·1
Groundnut cake	0·56	50·4
Mustard cake	3·2	29·1
Wheat bran	0·23	12·6
c. Mineral Supplements—		
Chalk powder	0·18	87·0
Sambar salt	0·50	4·0
Rock salt	0 22	4·0
Mineral mixture	83·6 81·6	278·0

It will be seen that all the grasses are sound in the young stage regarding both cobalt and copper but some at the flowering stage are either bordering on the marginal side or becoming deficient. It is also of interest to see that with increasing age there is a gradual decrease in the contents of cobalt and copper Napier grass,

maize plants, cowpeas, berseem are very sound with respect to such elements of which leguminous varieties are found to be the best.

Of the legumes examined berseem is extraordinarily rich in cobalt which is rarely met with in any of the pasture and forage crops usually administered as cattle feed. Bhusa, wheat bran, and crushed seeds (*e.g.*, maize, barley, oats, peas, gram) are quite good in cobalt contents but their copper values are marginal or sound. The oilcakes are considerably rich and will work as a very good supplement for poorer qualities of cattle feeds when supplied in combination. Chalk powder is very rich with respect to copper and sound in cobalt. The two salts (*e.g.*, sambar and rock) have marginal values for copper and sound values for cobalt. Further work is in progress.

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REFERENCES

Beeson, K. C. *et. al.* (1947). *J. Amer. Soc. Agr.* 39, 356

Bowstead, J. E., and J. P. Sackville (1939). *Canad. Jour. Res.* 17

Bowstead, J. E., J. P. Sackville and R. D. Sinclair (1942). *Sci. Agr.* 22, 314-25

Holmes, R. S. (1945). *Soil Sci. 59,* 77-84

Hood, S. L., Parks, R. Q., Hurtz, Chas (1944). *Ind.* and *Eng. Chem. Anal. Ed.* 16, 202-20

Mirchandani T. J. and Dabadghao P. N. (1949). *Sci. cult.* 14, 433

Russell, F. C. (1944). *Imp. Bur. Ani. Nutr. Tech. Com.* 15

Stiles, W. (1946). Trace elements in plants and animals

Sandell, E. B. (1944). Colorimetric determination of traces of metals

MANGANESE STATUS OF SOME INDIAN SOILS

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Whatever may be said about the function of 'micronutrient or trace elements' found in minute quantity in the tissues of plants and animals, the essential role played by these elements in the nutrition and metabolism of living beings is established beyond any controversy. Manganese a member of this group is as just important as any one of the ten classical major elements. Supply of this element below or above certain limit is reflected in the health of plants by the appearance of characteristic symptoms and this may ultimately lead to the decrease in yield or in severe cases total failure of crops. The nutritional diseases attributed to manganese occur widely in America, England, Australia. They are so common and widespread as to be designated by common names, e.g., 'Grey-speck' of oats, 'Pahala blight' of sugarcane, 'Marsh-spot' of peas, etc. In India these types of nutritional diseases attributed to trace elements have been reported by several workers. Mukherjee [1949] reported deficiency disease due to manganese and zinc in the case of citrus in Coorg, Madras, and Lyallpur. Daji [1948] attributed 'Band disease' of Areca palm to the manganese-toxicity. Das and Motiramani [1949] observed 'Top-yellowing' of gram to be due to manganese deficiency. In some places it is a common practice to include manganese in the common fertilizer schedule and this gives good results. To cite one example, 100 bushels per acre increase in yield of potatoes was obtained by the application of manganese sulphate in Michigan muck soils [Harmer, 1941]. The immense importance of manganese in the economy of plants and animals has been indicated by several authors [Browning, 1937 ; Stiles, 1946].

Only a portion of total amount of manganese present in soil is assimilable by plants. Manganese occurs in soil in the form of water soluble, exchangeable and higher oxides. These oxides have various composition from MnO_2 to Mn_3O_4 and differ in their oxidizing capacity. The view at first prevailed that only water soluble and exchangeable manganese can be utilised by plants [Steenberg, 1935 ; Heintze, 1938]. But this view was unable to explain certain observations when Leeper [1935] proposed the theory that not only exchangeable but also a portion of the higher oxides can also be assimilated by plants either by direct absorption in colloidal form or by reduction at the root surface, these oxides are reducible by easily oxidisable organic substances such as quinol, hydroxylamine, etc. and were termed by him as 'Reducible oxides'. This he determined by extraction with a neutral normal salt solution containing 0·2 per cent hydroquinone. Leeper's method was accepted though in a modified form by several workers in the U. S. A. [Sherman and Harmer, 1943], England [Twyman, 1944] and India [Mukherjee, 1949]. Rest of the

oxides are termed 'inert oxides'. The term 'active manganese' includes water soluble, exchangeable and reducible forms. These forms remain in equilibrium in soil as postulated by Sherman and Harmer [loc. cit.] as follows:

Manganous Mn $\rightleftharpoons$ Colloidal hydrated MnO_2 $\rightleftharpoons$ inert oxides and this equilibrium is influenced by several factors such as soil reaction, etc.

The variation in different forms of this element in different soil groups and soil types and evaluation of a soil regarding its manganese status is an important study. Data on Indian soils are lacking. The present study aims in having a preliminary idea about the manganese status of Indian soils and this will form basis for further lines of work and also to study the influence of soil and climatic factors on the relative amounts of different forms of manganese found in the soils.

Materials and methods

Forty surface soils upto the depth of 1 ft. from 40 profiles of virgin soil from different places all over India (undivided) formed the basis of this study. The names of the stations and the corresponding provinces are given below:

Assam—Jorhat, Sylhet, Karimgunj ; Bengal—Dacca, Rangpur ; Bihar—Ranchi, Pusa, Padrauna ; Uttar Pradesh—Shahjahanpur ; Madhya Pradesh—Nagpur, Akola, Waraseoni, Labhandi, Kheri-adhartal, Powerkhera ; Central India—Indore, Kharua ; Ajmer-Merwara—Makrera, Tabiji ; Madras—Coimbatore, Taliparamba, Koilpatti, Hagari, Nandyal, Samalkot, Anakapalle, Berhampur ; Bombay—Padegaon, Surat ; Sind—Sakrand, Karachi, Mirpurkhas ; Punjab—Mianwali, Lyallpur, Kangra, Gurdaspur, Lahore ; the N. W. F. P.—Haripur-Hazara, Peshawar. The soils have wide variation in their colour, texture, reaction and also in the climatic condition under which they are formed. Description of these soils are given by Viswanath and Ukil [1944].

Leeper's method as modified by Sherman, McHargue and Hodgkiss [1942] was adopted for the determination of water soluble, exchangeable and reducible forms of manganese by leaching 25 gm. of soil successively with water, N. ammonium acetate solution at pH 7·0 and N. ammonium acetatesolution containing 0·2 per cent hydroquinone (250 c.c. of solution was used in each case). Total manganese was determined by fusion with potassium bisulphate [Wright, 1939]. In the final stage permanganate colour was developed by oxidation with potassium periodate [Willard and Greathouse, 1917] in the medium of sulphuric acid except in the case of exchangeable form in which case phosphoric acid was used. A suitable aliquot was compared in Nesseler's tube with a standard solution containing 0·05 mg. of manganese per c.c. The data on pH, $CaCO_3$, and mechanical analysis are taken from the published work of Viswanath and co-workers [loc. cit.].

Results and discussions

The data on different forms of manganese along with the relevant physical and chemical characteristics are presented in Table I and the data on total, active, exchangeable and water soluble forms are discussed respectively to find correlation, if any, with the soil and climatic factors.

TABLE I

Manganese (in p.p.m.)

Soil number	Station	N.S.Q.	Climatic zone	Colour	Texture	*p*H	$CaCO_3$ Percentage of	Clay Percentage of	Silt Percentage of	Water-soluble	Exchange-able	Reducible	Active	Total	Ratio (Active Total)
2	Haripur	102·1	Arid	Brown	Clay loam	7·1	8·7	21·10	44·61	0·3	25·8	174·8	200·8	690·0	0·29
9	Lyallpur	60·6	„	„	Sandy	7·6	0·7	9·89	16·09	*nil*	11·0	96·6	107·6	437·0	0·25
10	Mianwali	67·1	„	Grey	„	7·3	6·4	13·60	13·18	*nil*	8·5	80·9	89·4	460·0	0·19
13	Mirpurkhas	32·0	„	„	„	7·3	9·9	16·24	24·57	*nil*	17·5	45·1	62·6	529·0	0·12
25	Akola	141·1	Semi-arid	Black	Clay	7·9	10·0	57·74	28·89	0·1	5·2	515·2	520·5	1081·0	0·48
31	Indore	167·3	„	„	„	7·8	4·7	65·40	19·25	*nil*	5·9	368·0	373·9	920·0	0·41
32	Kharua	149·9	„	„	„	7·5	3·5	52·70	22·70	0·3	8·1	358·8	367·2	1012·0	0·36
48	Padegaon	147·0	„	„	„	7·9	9·8	74·80	16·40	0·2	2·5	138·0	140·7	1104·0	0·13
49	Surat	202·2	„	„	„	7·2	1·3	47·10	19·50	*nil*	9·9	644·0	653·9	1426·0	0·45
52	Koilpatti	154·4	„	„	„	8·1	2·5	62·90	11·24	*nil*	1·6	460·0	461·6	1104·0	0·42
54	Hagari	91·2	„	„	„	8·8	7·1	43·95	19·49	*nil*	1·7	195·5	197·2	920·0	0·21
55	Nandyal	127·3	„	„	„	8·5	3·9	57·29	16·25	*nil*	5·9	414·0	419·9	1012·0	0·41
34	Tabiji	110·2	„	Brown	Sandy	7·2	1·0	5·04	6·65	0·6	15·6	44·2	60·4	287·5	0·21
50	Coimbatore	162·0	„	„	Sandyclay	7·1	1·0	31·67	6·74	0·5	14·7	133·4	148·6	391·0	0·38
57	Anakapalle	182·2	„	„	Sandy	7·9	0·1	9·48	7·26	2·1	62·6	151·8	216·5	529·0	0·41
60	Delhi	123·6	„	„	„	7·3	1·0	10·83	12·76	0·2	16·6	77·3	94·1	437·0	0·22
3	Lahore	105·8	„	Grey	Loam	8·2	1·9	17·66	31·76	*nil*	3·5	110·4	113·9	644·0	0·18
7	Gurdaspur	188·0	„	„	„	7·9	1·2	11·58	34·60	3·6	39·6	124·2	167·4	552·0	0·30
33	Makrera	104·8	„	„	Sandy	6·7	1·9	8·36	10·80	0·1	12·1	128·8	141·0	368·0	0·38
24	Nagpur	225·0	Humi	Black	Clay	7·3	2·7	59·55	19·63	0·2	4·8	828·0	833·0	1556·0	0·50
27	Labhandi	237·5	„	„	„	6·4	0·1	60·07	25·78	0·6	15·6	386·4	402·6	989·0	0·41
29	Kheri-Adhartal	304·6	„	„	„	7·5	0·5	49·35	19·91	0·3	8·1	377·2	385·6	920·0	0·42
30	Powerkhera	236·8	„	„	„	6·7	0·5	57·50	25·93	*nil*	5·5	285·2	290·7	828·0	0·35
56	Samalkot	223·0	„	„	Sandyclay	7·1	0·5	24·88	16·61	0·4	17·5	386·4	404·3	1196·0	0·34
18	Shahjahanpur	203·1	„	Brown	Loam	8·0	*nil*	18·58	33·06	0·4	15·6	69·0	85·0	299·0	0·28
26	Waraseoni	275·2	„	„	„	6·5	0·2	21·67	28·15	1·1	26·7	30·4	58·2	391·0	0·15
22	Ranchi	318·5	„	Red	Clay	6·6	*nil*	42·22	21·07	5·6	57·0	184·0	246·6	575·0	0·43
58	Berhampur	301·5	„	Grey	Sandy	6·1	0·1	12·84	2·61	0·8	30·4	142·6	173·8	368·0	0·47
8	Kangra	650·0	Per-humid	Brown	„	6·9	*nil*	11·55	28·82	4·9	47·8	119·6	172·4	621·0	0·28
35	Jorhat	1725·0	„	„	„	4·3	*nil*	6·80	8·22	0·7	9·9	6·4	17·0	391·0	0·04
36	Karimganj	1322·7	„	„	Loam	5·8	*nil*	20·95	41·28	4·8	81·0	43·7	129·5	552·0	0·23
37	Sylhet	1191·5	„	„	Sandy	4·8	*nil*	11·69	13·30	1·9	14·7	6·0	22·6	149·6	0·15
38	Dacca	579·2	„	„	„	5·7	*nil*	19·93	26·60	0·9	37·7	22·1	60·7	276·0	0·22
51	Taliparamba	762·4	„	Red	Clay	4·7	*nil*	29·59	26·11	2·9	49·7	29·4	82·0	805·0	0·10
39	Rangpur	694·8	„	Grey	Sandy	5·7	*nil*	6·41	24·08	1·9	18·4	14·7	35·0	437·0	0·08
1	Peshawar	69·2	Calcareou	..	„	7·9	18·2	11·90	30·85	0·3	7·4	125·1	132·8	782·0	0·17
11	Sakrand	30·8	„	..	„	7·7	11·9	9·37	31·14	*nil*	4·9	51·5	56·4	529·0	0·11
12	Karachi	35·7	„	..	„	7·1	22·5	6·57	8·06	*nil*	4·5	69·9	74·0	414·0	0·18
19	Padruana	328·0	„	..	„	7·7	34·4	9·78	14·02	*nil*	15·2	39·6	54·8	299·0	0·18
59	Pusa	207·9	„	..	„	7·3	36·0	5·62	23·68	*nil*	15·2	52·9	68·1	368·0	0·19

A. *Total manganese*

Table I shows that the soils have wide variation in their contents of total manganese. The variation observed is from 149·5 p.p.m. in the case of Sylhet to 1656·0 p.p.m. in the case of Nagpur. Relationships to colour, texture and climate are shown by considering them in individual groups.

1. *Colour*

Colour	Black	Red	Grey	Brown
Mean (in p.p.m.)	1089·8	690·0	479·2	419·3
S. E.	±49·0	±125·0	±51·0	±49·0

Significant at 1 per cent.

2. *Texture*

Texture	Clay	Sandy-clay	Clay-loam	Loam	Sandy-loam
Mean (in p.p.m.)	1072·4	793·5	690·0	487·6	426·8
S. E.	±76·7	±53·5	±217·1	±97·1	±51·8

Significant at 1 per cent.

The soil terminiology adopted is that of Whitney as modified by Davies and Bennet [1927].

3. *Climate*

Climatic Group	Humid	Semi-arid	Arid	Calcareous	Per-humid
Mean (in p.p.m.)	802·4	875·3	529·0	478·4	461·7
S. E.	±109·0	±84·5	±163·6	±146·3	±123·6

Not significant

The climatic group adopted is that of Viswanath and Ukil [1944]. Contents of manganese decrease with decrease in the clay content and the clayey soils have the highest amount of total manganese. The same observation was made by Carlyle [1931] who reported that the clayey soils of Texas contain high amounts of total manganese Soil in the humid and semi-arid region have high amounts of total manganese compared to other groups whereas soils of the per-humid region are very low in this respect. These soils are under the influence of high rainfall and

have loamy to sandy texture. These conditions along with low *p*H of the soils are favourable for the formation of bivalent manganous ions which being very mobile are either leached into the sub-soil or carried away with drainage water. This explains the low content of manganese [*cf*. Leeper, 1938].

The black soils are characteristically high in their contents of total manganese. The black soils mostly situated in humid and semi-arid region are well-known for their high fertility. These soils are highly argillaceous and are derived from (1) basic or intermediate granites and schists with rocks formed from magma rich in lime and magnesium bearing minerals (2) from sedimentary rocks such as Cuddapah and Karnool formations (3) from basaltic or trap rocks.

According to Goldschmidt [1945], in igneous rocks the distribution of trace constituents is controlled by the ionic radii of the elements concerned. Elements present in trace amounts in magma from which the rocks are crystallising are included in the crystals lattice of these minerals which contain a major constituent of equivalent ionic radii (± 15 per cent difference is permissible) and are thus concentrated in these rocks which contain that particular mineral. In such typical ferromagnesian minerals as olivines, pyroxanes, amphiboles, and biotitic micas Mg^{++} (0·78A), Fe^{++} (0·83A) which are themselves interchangeable, are replaced by such constituents as $Li,^{++}Ni^{++}$ Co^{++}, Zn^{++}, Mn^{++} (0·91A) and others of similar ionic radii. According to the same author ' the process of weathering and cycle of formations of sedimentary rocks in many respects parrallel the operations of gigantic semi-quantitative chemical analysis, involving large scale chemical separations'. The operations are mainly characterised by the separation of products. One of such products is ' Oxidases such as many sedimentary iron and manganese ores, with oxides and hydroxides of trivalent iron and tetravalent manganese. Nature of formation of the black soils thus explains the high concentration of manganese in them.

Again, the black soils have the predominance of montmorillonitic types of clay-minerals [Mukherjee *et al.* unpublished] which have high fixation capacity and further the octahedral position in the clay mineral of the montmorillonitic group may to some extent be occupied by manganese [Nagelschmidt, 1944]. All these facts explain the high content of manganese in black soils. In this connection it is to be noted that Iyer and Rajagopalan [1936] also, found the black soils to have high content of manganese (in some Indian soils).

B. *Active manganese*

As discussed previously in addition to the readily available bivalent manganese, a portion of higher oxides ' easily reducible manganese oxides ' can also be assimilated by plants [Leeper, 1935]. The term ' active manganese ' includes the sum of water soluble, exchangeable and reducible manganese.

The variation observed in the amount of active form in the soils studied is from 17·0 p.p.m. in the case of Jorhat to 833·0 p.p.m. in the case of Nagpur.

Significance in the colour, texture and climatic groups along with the means, standard errors are given below :

1. *Colour*

Colour	Black	Red	Brown	Grey
Mean (in p.p.m.)	419·3	164·3	105·6	97·5
S. E.	±38·9	±81·3	±31·9	±31·2

Significant at 1 per cent.

2. *Texture*

Texture	Clay	Sandy-clay	Clay-loam	Loam	Sandy
Mean (in p.p.m.)	391·9	276·4	200·8	110·8	91·1
S. E.	±47·2	±94·4	±133·4	±59·7	±31·5

Significant at 1 per cent.

3. *Climatic group*

Climatic group	Humid	Semi-arid	Arid	Calcareous	Per-humid
Mean (in p.p.m.)	320·0	271·8	115·1	77·3	74·2
S. E.	±54·1	±41·9	±81·2	±72·6	±61·4

Significant at 1 per cent.

As in the case of total manganese black soils have the highest content of total active manganese and also high ratio of active to total manganese about 0·5 compared to other colour groups. The soils in the humid region and semi-arid regions have higher amounts of it than the rest. The active manganese contents decrease with decrease in the clay content of the soils. Clay is an active part of the soil and it is the seat for the plant nutrients. Thus with increase in the clay content increase in the plant nutrient also is very much expected.

Regarding the relationship of the active manganese content to the pH of the soils maximum values are obtained in the region of pH between 6·0 and 7·5. In the case of soils, highly acidic, alkaline or calcareous the amount of active manganese and also the ratio of active to total manganese are very low. This observation is interesting in the sense that deficiency diseases due to manganese have been found to occur on soils which are highly alkaline or acidic [Harmer, 1942 ; Hunter, 1942 ; Camp and Peech, 1938]. In acidic soil low amount may be due to dearth of this element whereas in the case of highly alkaline soils low amount is due to unfavourable reaction though the total amount may be considerable.

The influence of predominating clay minerals on the relative amounts of active manganese is evident from the striking difference between black and acidic soils, the former having highest and the latter having lowest. As suggested by Leeper [1947] ' montmorillonitic soils having high fixation capacity and neutral to slight alkaline reaction can fix large amounts of active manganese whereas kaolinitic soils

are associated with leaching and low *p*H, the mobile manganese in this case is either quickly absorbed by plants or are removed in drainage water. Now as reported by Mukherjee *et al.* black soils and acidic soils (Dacca, Jorhat, Rangpur, etc.) respectively contain predominantly montmorillonitic and kaolinitic types of clay minerals. The effect of clay minerals present is evident. This supports Leeper's view. The soils mentioned last are lateritic and their low content of active manganese receives support from the work of Teakle and Wild [1940] who reported manganese deficiency to be associated with lateritic types of soil. It is further supported by the recent observation of manganese deficiency disease in citrus in Coorg on lateritic and red loam soils occurring in the high rainfall area. (Unpublished work at Indian Agricultural Research Institute, New Delhi).

As mentioned earlier difference in the content of manganese (active) can be explained by the equilibrium postulated by Sherman and Harmer [1942] :

Manganous $Mn^{++} \rightleftharpoons$ Colloidal hydrated $MnO_2 \rightleftharpoons$ inert MnO_2

More more acidic the soils more is the equilibrium shifted towards the left whereas alkaline condition has the reverse reaction.

C. *Exchangeable manganese*

This is the bivalent form of manganese which is extracted with neutral normal salt solution at *p*H7·0. This constitutes a very small fraction of total manganese. The amount varies in these soils from 1·6 p.p.m. in the case of Koilpatti to 81·0 p.p.m. in the case of Karimgunj.

Significance in the colour, climate and texture groups is given below :

1. *Colour*

Colour	Red	Brown	Grey	Black
Mean (in p.p.m.)	53·3	29·2	14·8	7·1
S. E.	±10·2	±4·0	±4·2	±4·0

Significant at 1 per cent.

2. *Climatic group*

Climatic group	Per-humid	Humid	Arid	Semi-arid	Calcareous
Mean (in p.p.m.)	37·0	20·1	15·7	13·7	9·4
S. E.	±6·4	±5·7	±8·5	±4·4	±7·6

Significant at 5 per cent.

3. *Texture*

Texture	Laom	Clay-loam	Sandy	Sandy-clay	Clay
Mean (in p.p.m.)	33·3	25·8	19·4	16·1	5·1
S. E.	±7·9	±17·6	±4·1	±12·4	±6·2

Not significant.

Unlike in the cases of active, and total manganese, black soils are very low in their contents of exchangeable manganese. The amount of exchangeable manganese decrease with increase in clay content of the soils. Climate has marked influence on the contents of exchangeable manganese. It is evident from the observation that the amount of exchangeable manganese gradually decrease with decrease in the humidity of the climate, with the exception in arid region where slight increase is observed. The slight increase in the arid climate may be due to high surface soil temperature which influence in increasing the exchangeable manganese [Sherman and Fujimoto, 1946].

Manganese has been found to be one of the most easily exchangeable bases [Ruprecht and Morse, 1917] specially under acid conditions [Mattson, 1926]. High rainfall and acid soil reaction favour the formation of mobile bivalent manganous ions [Endredy, 1940]. These conditions explain the observation that soils of the per-humid region which are subjected to much leaching have high amount of water soluble and exchangeable manganese. Under such reducing conditions in presence of organic matter, most of the reducible oxides of manganese are liable to be converted into bivalent forms and this is supported by the observation that in some cases the easily reducible manganese is less than that of exchangeable form. In this per-humid region the rainfall is high, the soils are acidic and sandy to loamy in texture. So under prevailing conditions most of the active manganese which has become mobile manganous ions are either leached into the sub-soil or are carried away with drainage water. The soils in this group are lateritic, so it may be concluded that lateritic soils containing high replaceable manganese.

In the humid region the influence of the reducing condition is less marked. Here the amount of bivalent manganese is less than that in the per-humid region in spite of their high content of total manganese. The above reasoning holds good in the case of soils of the semi-arid region also.

In the arid region the amount of bivalent forms are low compared to those of per-humid region and compared to the content of active and total manganese. This observation is similar to that of Craig [1936] who reported that leached soils of Mauritius have high content replaceable manganese whereas soils of dry districts are low in these respects.

The influence of pH and $CaCO_3$ is very characteristic. Increase in both the pH and amount of $CaCO_3$ in soils is followed by the decrease in the amount of exchangeable manganese and this is in conformity with the observation that liming decreases the amount of exchangeable manganese [Funchess, 1919 ; Masoni, 1916].

D. *Water soluble manganese*

This form of manganese is very very small in amount compared to other forms of manganese present in soil. In some soils the amount of this form is practically absent and the maximum amount found is 5·6 p.p.m. in the case of Ranchi. The nature of this form is similar to that of exchangeable manganese *e.g.*, the amount increases with increase in humidity. The soils in the per-humid region have the

highest amounts of water soluble manganese. More acidic the soil, more is the amount of water soluble manganese and *vice versa*.

Summary and conclusions

Data are presented on different forms of manganese— water soluble, exchangeable, reducible, active and total -- of forty surface soils (0-1 ft.) from different places of India (undivided). The soils are virgin and have wide variation in their colour, texture and in the climatic conditions under which they are formed. Wide variation in the distribution of different forms of manganese all over India is indicated. The manganese status of the soils is found to be greatly influenced by the soil and climatic factors. Significant correlation has been observed between manganese content of the soils and their colour, texture, amount of $CaCO_3$ reaction and predominating clay minerals. (By manganese status is meant the different forms mentioned above.) As to the relationship to climate, leaching has great influence on the relative amounts of different forms of manganese in these soils.

A summary of the main results obtained are given below :

Black soils which contain predominantly montmorillonitic types of clay minerals have low amounts of water soluble and exchangeable manganese but are characteristically high in their content of total and active forms. Lateritic soils are low in active and total manganese but high in replaceable forms.

Soils of the per-humid region are relatively high in water soluble and exchangeable manganese but low in amounts of active and total forms whereas soils of humid and semi-arid regions have high content of total and active manganese but low amounts of bivalent forms. As the climate changes from humidity to aridity the amounts of water soluble and exchangeable manganese decrease gradually.

Increase in the clay content of the soils is associated with decrease in the amount of water soluble and exchangeable forms but increase in active and total manganese. Sandy soils are very low in active and total forms.

The relative amounts of replaceable forms in the soils are greatly influenced by the soil reaction and presence of $CaCO_3$. Increase in the soil reaction (pH) and amount of $CaCO_3$ is followed by decrease in the amount of bivalent forms of manganese and *vice versa*. Calcareous soils and soils having high pH have low amount of active manganese.

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REFERENCES

Browning, E. (1937). Manganese and cobalt in plant and animal economy. *Sci. Prog.* **32,** 276-289

Camp, A. F. and Peech, M. (1938). Manganese deficiency in citrus in Florida. *Proc. Amer. Soc. Hort. Sci.* **36,** 81-85

Carlyle, E. C. (1931). Manganese in Texas soils and its relation to crops. *Texas Sta. Bull.* **432,** 37

Craig, N. (1936). Base exchange relationships in Mauritius soils. Mauritius Sugarcane. *Res. Sta. Bull.* **9,** 24

Daji, J. A. (1948). Manganese toxicity as a probable cause of the Band-disease of Areca Palm. *Curr. Sci.* **17,** 259-60

Das, S. C. and Motiramani, D. P. (1949). A preliminary note on diseases of gram. *Curr. Sci.* **18,** 45-46

Davis, R. O. E. and Bennet, H. H. (1927). U. S. D. A., Dept. Circ. 19

Endredy, E. (1940). The exchangeable-manganese content of soils. *Chem. Abs.* **34,** 7052

Funchess, M. J. (1919). Acid soils and the toxicity of manganese. *Soil Sci.* **8,** 69

Goldschmidt, V. M. (1945). The Geochemical background of minor element distribution. *Ibid.,* **60,** 1-7

Harmer, P. H. (1941). The muck soils of Michigan. *Mich. Agric. Sta., Spl. Bull.* **314**

———(1942). The occurrence and correction of unproductive alkaline organic soils. *Soil Sci. Soc. Amer., Proc.* **7,** 378-386

Heintze, S. G. (1938). Readily soluble manganese of soils and Marsh spot of peas. *J. agric. Sci.* **28,** 175-186

Hunter, J. G. (1942). A chlorosis of bracken due to manganese deficiency. *Nature*, 150, 578-79

Leeper, G. W. (1935). Manganese deficiency of cereals. Pot experiments and a new hypothesis *Proc. Roy. Soc.* Victoria, **47,** II, 225-61

——————— (1938). The chemistry of minor elements in plant nutrition. *Australian Chem. Inst. Jour.* and *Proc.* **5,** 417-25

——————— (1947). Forms and reactions of manganese in the soils. *Soil Sci.* **63,** 79-94

Masoni, G. (1916). Quoted by Jacks and Scherbatoff in *Imp. Bur. Soil Sci., Tech. Comm.* 39

Mattson, S. (1926). Electrodialysis of the colloidal soil material and the exchangeable bases. *J. Agric. Res.* **33,** 553-567

Mukherjee, J. N. (1949). Trace element deficiencies in citrus. *Sci. and Cul.* **15,** 235-37

Nagelschmidt, G. (1944). Mineralogy of soil colloids. *Imp. Bur. Soil Sci., Tech. Comm.* 42

Ruprecht, R. R. and Morse, F. W. (1917). The cause of the injurious effect of sulphate of ammonia when used as a fertilizer. *Mass. Agric. Expt. Sta. Bull.* **176,** 134

Sherman, G. D. and Fujimoto, C. K. (1946). The effect of the use of lime, soil fumigants and mulch on the solubility of manganese in Hawaiian soils. *Soil Sci. Soc. Amer., Proc.* 11, 206-210

——————— and Harmer, P. H. (1942). *Ibid., Proc.* **7,** 398-405

——————— and McHargue, J. S. and Hodgkiss, W. S. (1942). Determination of active manganese in soil. *Soil Sci.,* **54,** 253-7

Steenbjerg, F. (1935). The exchangeable manganese in Danish soil and its relation to plant growth. *Trans. 3rd. int. Cong. Soil Sci.,* 1, 198-201

Stiles, W. (1946). *Trace elements in plants and animals.*, Cambridge.

Teakle, L. J. H. and Wild, A. S. (1940). Some soil types associated with manganese deficiency of cereals in Western Australia. *J. Dept. Agric. W. Aust.* **17.** 223-33

Twyman, E. S. (1944). Manganese deficient soils. *Nature*, 154, 336

Viswanath, B. and A. C. Ukil (1944). Comparative studies of Indian soils. *Indian J. agric. Sci.* **14**, 333-44

Willard, H. H. and Greathouse, L. H. (1917). The colorimetric determination of manganese by oxidation with periodate. *J. Amer. Chem. Soc.* **39**, 2366-2377

Wright, C. H. (1939). *Soil analysis*, Thoamas Murby & Co., London

MUTATION IN GRAM (*CICER ARIETINUM*)

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IMPROVEMENT of gram by selection and hybridisation was started in the year 1932 at Coimbatore, by collection of types maintained or evolved by other workers in India and abroad. During a study of the new varieties, it was found that some of them which were pure for all morphological characters for over three years, threw occasionally odd offtypes which in their turn bred true to the parental forms in all respects. Changes were observed in pigmentation of stem, flower or seed coat, sizes of plant parts or seed and in surface of the seed. Inspite of extreme care taken in preventing accidental mechanical mixtures at harvest and sowng periods, some of the new types recurred in their appearance and behaved as mutants in later generations. The present paper summarises the results of observations made on the frequency of occurrence of such mutations.

Details of the gram types --ten from Indian Economic Botanist, Pusa and two from Coimbatore—throwing mutants, their genic constitutions before and after change, the percentage mutational rate and the number of genes affected are furnished in Table I. The factorial constitutions given in the table follow the formulae adopted by Ramanathan and Balasubrahmanyan [1936] and Balasubrahmanyan [1937]. It may be seen from the table that all the seven genes show a tendency to mutate, three factors *viz.* C, B and P mutate with equal ease in both recessive and dominant directions, and the number of factors affected at a given time is never more than two. The mutants obtained from Coimbatore types 426 and 498 and two Pusa types T69 and T81 were entirely new and not described before by Shaw and Khan [1931]. The changes in the Coimbatore types were similar being confined to petal and seed coat colours only. The white flowered mutants retained their adaptability, growth, habit and earliness of the parental types and were in marked contrast to the late and shy yielding Pusa varieties. T69 and T81 threw a common mutant possessing increases in the size of all morphological characters together with differences in seed colour, shape and surface. The measurements given in Table II for the mutant obtained from T 81 will also hold good for the one isolated from T-69. It may be noted that the size of certain parts like branches, leaves and seeds is nearly doubled giving the appearance of gigant. The chromosome number however was found to be 16(2n) in both the parents and the mutants.

The off types thrown by the remaining eight varieties agreed with one or other of the type collections maintained at Coimbatore.

Ramanathan and Balasubrahmanyan [1935] have shown that gram was one hundred per cent self fertilised crop and as such the occurrence of the new true breeding types through natural cross fertilisation should be excluded. The fact

TABLE 1

Mutating factors and their frequency

Parent type*	Genic constitutions of petal colour, seed coat colour and seed coat surface		Factors affected	Petal	Nature of change				Total population	Number of mutants recorded	Percentage of mutation
	Parent	Mutant			Seed colour grade	Seed surface	Singleness of flower on pedical	Gigantism			
T.7	$CbPSt^2t^1F^rr$	$CBPSt^2t^1f^rr$	$B\ F^r$	White to pink	2 to 8	Wrinkled to smooth.	No change	No change	80	1	·0125
T.10	$CbPST^2t^1f^rr$	$CBPSt^2t^1f^rr$	B	do.	3 to 10	No change	do.	do.	800	1	·0012
T.11	$cBpST^2t^1f^rr$	$CBPSt^2t^1f^rr$	C P	do.	7 to 10	do.	do.	do.	1,120	1	·0009
T.69	$CBPST^2t^1f^rR$	$CBPST^2T^1F^rR$	T^oF^r	No change	10 to 13	do.	do.	Small to big	2,000	1	·0005
T.81	$CBPST^2T^1f^rr$	$CBPST^2T^1F^rR$	F^rR	do.	12 to 13	Smooth to rough	do.	do.	2,100	5	·0024
T.82	$CBPST^2t^1f^rr$	$CBPSt^2t^1f^rr$	S	do.	No change	No change	Double to single.	No change	1,950	1	·0005
426	$CBPST^2t^1f^rr$	$CbPSt^2t^1f^rr$	B	Pink to white	10 to 3	do.	No change	do.	720	5	·0071
498	$CBPST^2t^1f^rr$	$CbPSt^2t^1f^rr$	B	do.	do.	do.	do.	do.	640	1	·0016
T.6	$CbPST^2t^1f^rr$	$CBPSt^2t^1f^rr$	$B\ T^2$	White to pink	1 to 10	do.	do.	do.	800	3	·0038
T.8	$CbPSt^2t^1F^rr$	$CBPSt^2t^1f^rr$	B F′	do.	2 to 8	Wrinkled to smooth.	do.	do.	640	1	·0016
T.10	$CbPST^2t^1f^rr$	$CBPSt^2t^1f^rr$	B P	White to blue	3 to 7	No change	do.	do.	1,400	3	·0021
T.12	$cBPST^2t^1f^rr$	$CBPSt^2t^1f^rr$	C	White to pink	No change	do.	do.	do.	840	1	·0012
T.24	$CBPST^2T^1f^rr$	$cBPSt^2t^1f^rr$	$C\ T^o$	Pink to white	12 to 10	do.	do.	do.	880	1	·0011

*Types with prefix T are from Pusa

TABLE II

Characters studied	T-81	T-81 mutant
Average length of main branches	252 mm.	410 mm.
Average length of internode	9·8 mm.	15·3 mm.
Average number of leaflets per leaf on main stem	14	16
Average length of stipule	4·7 mm.	11·7 mm.
Average breadth	4·7 ,,	7·6 ,,
Average length of leaf	7·7 ,,	12·5 ,,
Average breadth	4·9 ,,	8·8 ,,
Average length of flower standard	7·8 ,,	9·3 ,,
Average breadth	7·1 ,,	8·5 ,,
Average length of pod	14·4 ,,	20·9 ,,
Average breadth	8·2 ,,	10·9 ,,
Seed weight per seed	161 mg.	275 mg.

that some of the types threw the same type of mutants when every kind of precaution was taken to rule out chances for inadvertent mechanical mixtures, should be considered as additional proof for their mutational origin. Environment is known to have a profound effect on the frequency and intensity of mutational rates in plants. It is possible that the gram types normally grown in colder regions of the North India experienced a violent change when transported to the temperate south. The rates of mutation recorded in the Statement 1 would compare very favourably with those noticed by Dunning [1930] and Altenberg [1934] in wasps and flies. Mutations have been previously recorded in gram by Ramanujam and Singh [1945], Ekbote [1937] and Dixit [1932]. They were recessive leaf changes except the gigant obtained by Dixit in T-22. It is rather noteworthy that the mutations in the dominant direction are more preponderant than those in the recessive side. Only three out of thirteen of the mutants are recessive. The tendency of factors C, B and P for reverse mutations probably shows that their mutability is comparatively high.

SUMMARY

Mutations occurred in twelve gram types studied at Coimbatore.

Dominant mutation was more common than recessive. Factors C, B and P were highly mutable showing a tendency for reverse mutations.

Two of the thirteen mutations were new. One of them was a gigant exhibiting increases in size of plant organs.

The rates of mutation ranged from 0·0005 to 0·0125 per cent.

Changes in environment and higher mutability of certain genes were adduced as probable causes.

REFERENCES

Altenburg (1934). *Amer. Nat.*, 68

Balasubramaniam, R. (1937). *Madras agric. J.*, 26

Dixit, P. D. (1932). *Indian J. agric. Sci.*, 2

Dunning (1930). *Genetics.* 16, 505

Ekbote, R. B. (1937). *Curr. Sci.*, 5

Ramanatha Ayyar, V. and Balasubrahmanyan, R. (1935). *Madras agric. J.*, 23

Ramanatha Ayyar, V. and Balasubrahmanyan, R. (1936). *Proc. Ind. Acad. Sci.*, 4

Balasubrahmanyan, R. (1937). *Madras agric. J.*, 15

Ramanujam, S and Singh, H. B. (1945). *Indian J. Gen.* and *Plant Breed*, 5

Shaw, F. J. F. and Abdur Rahman Khan, (1931). *Mem. Dep. Agric. Ind.*, 19

CO-ORDINATED MANURIAL TRIALS ON RAINFED COTTON IN PENINSULAR INDIA

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(With four text-figures)

A REVIEW of the past manurial trials on cotton in India [Panse, 1945] has shown that except under conditions of soil salinity or inadequate rainfall cotton, both irrigated and rainfed, gives a universal response to nitrogenous fertilisers, specially ammonium sulphate and organic manures like oilcakes of groundnut, toria (mustard), and neem (margosa). There was, moreover, definite evidence that the level of soil fertility, which is an integrated result of all known and unknown factors which determine yield, influences the degree of response to nitrogen also and under conditions of high yield, the response to a given quantity of nitrogen is also high and *vice versâ*. The review emphasized the need for further experimentation on a comprehensive and co-ordinated basis to determine optimum quantities of nitrogen for application and precise specification of the conditions governing the response of cotton to nitrogen, before the results of the manurial trials could be translated into cultivators' practice. Model layouts for such experiments on irrigated and rainfed cotton were also suggested. Co-ordinated experiments on rainfed cotton on the lines recommended in the review were commenced in 1943-44 at various research farms in the cotton tracts of peninsular India with the co-operation of the agricultural departments concerned and were continued up to 1947-48. The results of this series of experiments are summarized in the present article.

The most serious drawback of past trials, as brought out in the review, was that a range of nitrogen doses sufficiently wide to provide data for the determination of optimum doses was not tried, the quantities of nitrogen applied being limited to 40 or 50 lb. per acre on the view that larger doses would be uneconomic. Experimentation should, however, not be restricted by such considerations which tend to anticipate the result. Economics of the manuring of cotton is subject to a continual change, depending as it does upon the prevailing prices of cotton and cost of manure, apart from the rate of increased yield obtained by manuring. The correct approach to the study of the economics of manuring is to determine through adequately planned manurial trials the agricultural relationship between the quantity of manure and the increase in yield resulting therefrom under a given set of cultivation conditions. Once this relationship is established with requisite precision, it is a simple matter to calculate with its help profits to be expected from a given application of nitrogen as also the optimum or most profitable dose of nitrogen, with reference to any given cost of manure and price realised for cotton. The agricultural relationship between quantity of nitrogen and the resulting increase in

yield can be best expressed statistically for this purpose as a polynomial curve, termed the response curve, of the second or higher degree. It is obvious that response to nitrogen cannot be assumed to be linear i.e., proportional to the quantity of nitrogen except perhaps over a narrow range of small dressings. The law of diminishing returns comes into operation with larger doses and the response curve tends to bend downward as doses of nitrogen are increased. Within the range of experimental doses usually considered sufficient for a precise determination of this curve, a second degree parabola may be regarded as its adequate representation. Sukhatme [1941] has used this form of the response curve in studying the economics of manuring of paddy. Failure to appreciate this basic or primary objective of manurial experiments resulted in past trials in the application of doses which were too low to give conclusive results, and is also responsible for the criticism which is sometimes heard against the trial of large and apparently uneconomic doses in the modern trials.

The present series of trials was planned to determine the response curve for nitrogen applied to rainfed cotton on black soil. As recommended in the review, critical information was also sought on two other items, *viz.* (1) the relative efficiency of nitrogen in the form of ammonium sulphate and groundnut cake and (2) the comparison between the application of manure by broadcasting on the surface and drilling it into the soil. To study the response of cotton to nitrogen under varying conditions of soil fertility, the trials were simultaneously located on two or three fields known to have different levels of fertility, at each station.

Layout and distribution of the experiments :

In pursuance of the above objectives of these trials, each experiment was planned to include treatment combinations for the following factors :—

(1) Kind of nitrogen : ammonium sulphate, groundnutcake.

(2) Method of application : drilling, broadcasting.

(3) Doses of nitrogen : usually four and ranging from 0 to 60 lb. nitrogen per acre in the first year ; the range was increased to 80 lb. nitrogen per acre on good land and up to 100 lb. per acre on very fertile fields in subsequent years, as lesser quantities were found to be inadequate for determining the true shape of the response curve on such land.

Besides nitrogen in the above two forms *viz.* ammonium sulphate and groundnut cake, neem cake was a third form included in trials at Koilpatti in Madras State. It was found that this cake was as good as ammonium sulphate or groundnut cake in both seasons, 1944-45 and 1945-46 in which it was tried. Nitrogen was applied at or soon after sowing in all trials, except that in the trials in Hyderabad State a broadcast application about a fortnight before sowing was included as an additional treatment. The results obtained were, however, conclusive in showing that application at sowing was more effective than this earlier application. All trials were laid out in randomised blocks, usually with three replications and contained 16 to 30 treatment combinations. The layout plans were settled in consultation with the authors of the present article.

Fifteen experiment stations scattered in different cotton tracts of peninsular India and shown in Fig. 1 co-operated in project and carried out a total of 89 trials over a period of five years, 1943-44 to 1947-48. The distribution of these trials is shown in Table I.

TABLE I

Distribution of co-ordinated manurial trials on rainfed cotton

Region and station	Number of Trials					Total
	1943-44	1944-45	1945-46	1946-47	1947-48	
Madhya Bharat—						
Indore	2	2	2	2	..	8
Madhya Pradesh—						
Akola	2	2	2	2	..	8
Khandwa	..	..	2	2	2	6
Bombay—						
Baroda	..	..	1*	1*	..	2
Surat	..	1*	2	2	2	7
Jalgaon	1	2	2	2	..	7
Dhulia	1*	..	..	..	..	1
Hyderabad—						
Nandad	2	3	2+1*	3	..	11
Latur	3	2	2	2	..	9
Madhol	3*	3*	3*	3*	..	12
Madras—						
Koilpatti	3	2	2	..	..	7
Guntur	1	1	1	..	..	3
Nandyal	1	1	1	..	..	3
Hagari	2*	..	..	..	..	2
Coimbatore	1	1	1	..	..	3
Total	22	20	24	19	4	89

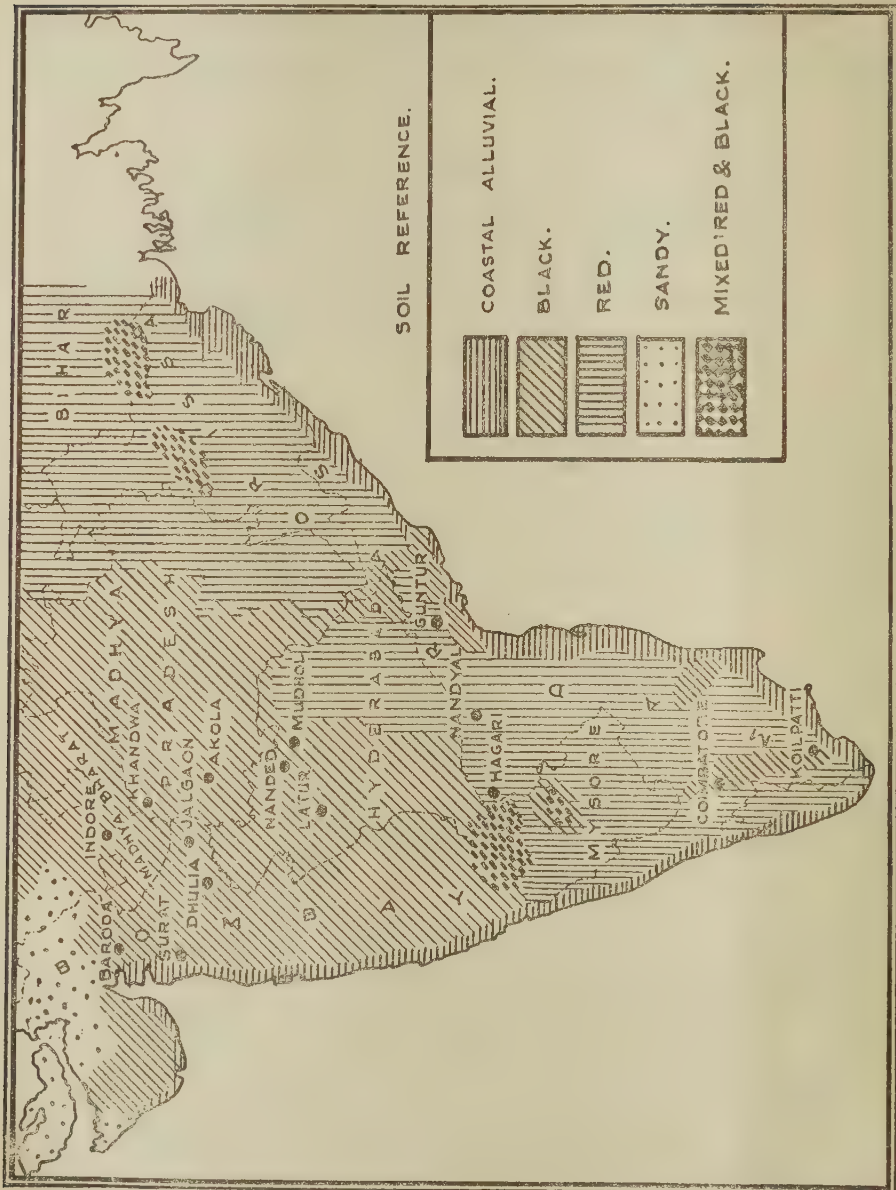

Fig. 1. Map of Peninsular India showing soils and location of stations at which co-ordinated trials were carried out

For the present study which relates to the black soil, 19 trials marked with an asterisk in the above table were omitted as not being representative. It may be recalled from the review of the past trials that response to manuring is poor or even adverse under conditions of scanty rainfall and consequently centres with such rainfall are not suitable for manurial experiments. Trials at Dhulia and Hagari have been omitted for this reason and were, in fact, discontinued after the first year. The experiments at Baroda were located on gorat soil and not on black soil. Similarly, at Madhol in Hyderabad State the experimental land was not typical black soil, but a much lighter red loam. The first trial at Surat in 1944-45 was vitiated owing to a very late application of manure on account of continuous rain and a trial at Nandad in rich field in 1945-46 was spoiled by an attack of *fussarium wilt.* Barring these cases, the remaining 70 trials were included in the present analysis. The annual rainfall at different stations during the years in which these 70 trials were carried out there is shown in Table II.

TABLE II

Annual rainfall in inches at experiment stations where co-ordinated manurial trials were laid

Station	1943-44	1944-45	1945-46	1946-47	1947-48
Indore	35·54	58·56	42·05	55·33	37·45
Akola	30·22	46·06	41·29	32·53	..
Khandwa	..	..	21·30	42·86	19·76
Surat	..	..	64·97	67·35	29·95
Jalgaon	33·48	40·51	29·18	41·77	..
Nandad	38·61	36·80	27·00	33·39	..
Latur	39·58	33·86	33·38	24·66	..
Koilpatti	17·77	38·71	29·84	..	..
Guntur	33·80	33·92	40·34	..	..
Nandyal	11·91	26·34	38·34	..	..
Coimbatore	17·92	32·80	29·25	..	

It will be seen that the annual rainfall ranges mostly between 25 and 45 in. at different stations and this represents the usual rainfall under which most of the rainfed cotton is grown on black soil.

Method of statistical analysis and results

The object of the present analysis is to obtain from the entire series of trials critical information concerning:

(1) The effectiveness of the two forms of nitrogen, *viz.*, ammonium sulphate and groundnut cake, in comparison to each other.

(2) The effectiveness of drilling the manure in comparison to the usual method of broadcasting, and

(3) The rate of response of cotton to nitrogen.

The influence of rainfall and soil fertility on these three factors has also been studied. Finally the economics of manuring has been examined in relation to soil fertility which has been shown to have a profound effect on the character of the response curve and formulae have been developed predicting the magnitude of response to a given dose of nitrogen and the optimum dose of nitrogen at any given level of fertility of the soil.

Corresponding to each individual trial an analysis of variance was carried out to test the statistical significance of the different factors including the linear and second degree components of the response curve. Appropriate mean values and the linear and quadratic coefficients of the response curves were also calculated. It was generally observed that there was no interaction between the different factors in a trial, or, in other words, these factors, *viz.*, the relative effectiveness of the two forms of nitrogen, the comparison between the two methods of application and the shape of the response curve, behaved as being statistically independent of one another. The values for the different factors averaged over all trials together with their standard errors calculated from variation between the trials are shown in Table III.

TABLE III

Average effects of different factors over all trials

Factor	Mean values in lb. seed cotton per acre	S. E.
Difference in response to ammonium sulphate and groundnut cake	14·9	9·1
Difference in response to drilling and broadcasting ammonium sulphate	1·6	7·7
Difference in response to drilling and broadcasting groundnut cake	12·7	6·7
Average rate of response to nitrogen, the linear coefficient of the response curve	2·465	0·240
Average rate of change in the linear coefficient or the quadratic coefficient of the response curve	0·0259	0·0042

On the average of all trials there was no significant difference between the two forms of nitrogen, ammonium sulphate and groundnut cake, although the numerical value of the difference is in favour of the former. Method of application also made no difference as far as ammonium sulphate was concerned, but for groundnut cake drilling appeared to give a small increase in yield over broadcasting, the difference approaching significance as judged by its standard error. Both the linear and quadratic coefficinets of the average response curve were highly significant, the quadratic coefficient being negative as it should be for a typical yield curve.

Each of these factors showed appreciable variation among different trials both in regard to the numerical magnitude of the effect and its statistical significance. Consequently the average results given above cannot by themselves provide a very useful basis in making practical recommendations on manuring. It is desirable to investigate the relationship between the effects observed in individual trials and the conditions of the trials in so far as these conditions are measurable. If such a relationship is found to exist, the effects to be expected under any given set of conditions could be predicted and this would form a reliable basis for making practical recommendations appropriate to specified conditions. The conditions available for study were the annual rainfall and soil fertility. Of course, in addition to total annual rainfall, its distribution over the season is also important in influencing yield and response to manure; but the examination is here confined to the effect of the total annual rainfall. With regard to soil fertility the average yield of a trial is employed as a measure of fertility. Yield is clearly the best index of soil fertility; but the reason for using the average yield of the whole trial in preference to that of the unmanured plots alone is a statistical one, in as much as comparisons based on the latter yield are shown to be biassed [Yaets, 1935]. The variation in the range of nitrogen dressings applied in the different trials introduces a complication in using the average yield of a trial as a measure of fertility; but a re-examination of the data by grouping the trials according to the range of nitrogen dressings applied showed that the conclusions were not affected by such variation.

A joint regression of the effect of each manurial factor on soil fertility and annual rainfall was calculated from which the separate contribution of soil fertility and rainfall to the combined relationship was further isolated. Considering that the trials were spread over different stations and different seasons and were also conducted simultaneously in different fields at the same station, three types of regression analyses are available. These are (1) regression within years within stations which would measure the relationship with soil fertility alone under identical rainfall and would thus be the best measure of this relationship; (2) regression between years within stations which would involve seasonal variation at the same station plus the average difference in soil fertility in different seasons at the same station resulting from a change of fields on which the trials were located in different seasons, and (3) regression between stations which involves average differences between stations and include the characteristic soil and rainfall differences between different stations. The second regression may be expected to bring out the influence of rainfall rather well since the average soil differences between seasons at the same station are not likely to be large while the third regression might not show any pronounced

effect of either soil or rainfall owing to the relatively homogeneous conditions that the soil fertility and annual rainfall at the different stations included in the present study represent.

The results of the regression analysis are shown in Table IV.

Table IV

Influence of fertility and rainfall on manurial comparisons

Analysis of variance for regression

Due to	Within years, within stations		Between years, within stations		Between stations	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
			Ammonium sulphate—Groundnut cake			
Joint regression on fertility and rainfall	..	..	2	1822	2	14683
Linear regression on fertility alone	1	47367**	1	10	1	20693
Balance due to regression on rainfall	..	..	1	3636	1	8672
Residual	31	5257	25	1955	8	13876
			Drilling—Broadcasting (ammonium sulphate)			
Joint regression on fertility and rainfall	..	..	2	6256	2	253
Linear regression on fertility alone	1	264	1	11048	1	313
Balance due to regression on rainfall	..	..	1	2004	1	194
Residual	30	2772	21	6143	8	2617
			Drilling—Broadcasting (groundnut cake)			
Joint regression on fertility and rainfall	..	..	2	1008	2	1149
Linear regression on fertility alone	1	1997	1	979	1	1825
Balance due to regression on rainfall	...	..	1	1038	1	474
Residual	30	2230	21	3655	8	4138
			Linear coefficient of response curve			
Joint regression on fertility and rainfall	..	..	2	30·53	2	24·12
Linear regression on fertility alone	1	14·99	1	54·85**	1	46·27**
Balance due to regression on rainfall	..	..	1	6·21	1	1·98
Residual	31	1·55	25	2·15	8	3·31
			Quadratic coefficient of response curve			
Joint regression on fertility and rainfall	..	..	2	0·00232	2	0·00071
Linear regression on fertility alone	1	0·00018	1	0·00379**	1	0·00006
Balance due to regression on rainfall	..	..	1	0·00086	1	0·00177
Residual	31	0·00141	25	0·00094	8	0·00154

** Significant on 1 per cent level

In order to further investigate the effects of soil fertility on these factors, mean values of responses to the various factors corresponding to three different levels of fertility are shown in Table V.

TABLE V

Manurial comparisons for three fertility groups

Group	Number of trials	Ammonium Sulphate	Groundnut Cake
		Mean lb. per acre	
Low fertility	13	—11·4	7·2
Medium fertility	30	2·1	6·1
High fertility	27	41·8	21·6
All trials	..	14·9	9·1

Group	Drilling—Broadcasting				Response Curve			
	Ammonium Sulphate		Groundnut Cake		Linear Co-efficient		Quadratic Co-efficient	
	Mean lb. per acre	S.E.	Mean difference lb. per acre	S.E.	Mean	S.E.	Mean	S.E.
Low fertility	—1·7	5·1	0·7	5·1	0·840*	0·274	—0·0052	0·0041
Medium fertility	—1·7	13·6	6·7	9·7	1·928**	0·322	—0·0361**	0·0081
High fertility	6·3	7·6	23·8	12·5	3·845**	0·283	—0·0243**	0·0051
All trials	1·6	7·7	12·7	6·7	2·465**	0·240	—0·0259**	0·0042

* Significant on 5 per cent. level.
**Significant on 1 per cent. level.

Their standard errors were calculated from variation between experiments within each group. For the construction of this table, all trials with an average yield upto 250 lb. per acre were classed together arbitrarily and this group was regarded as representing low fertility. Trials with yields between 250 and 500 lb. formed a group representing medium fertility and trials with yield above 500 lb. constituted a high fertility group. Conclusions derived from this analysis are discussed below.

(*a*) *Ammonium sulphate* vs. *groundnut cake.* In the comparison between the two forms of nitrogen, ammonium sulphate and groundnut cake, the effect of soil fertility was very clearly brought out in the first regression analysis, *viz.* within years within stations in Table IV. The nature of this effect will be seen from the mean values of the difference between the two manures corresponding to three different levels of fertility shown in Table V. It is seen from Table V that the difference between the response to ammonium sulphate and groundnut cake tended to increase with soil fertility; but it was only in the high fertility class that the

difference in favour of ammonium sulphate was almost significant. It may be concluded that both forms of nitrogen produce an almost equal response, except on highly productive soil where ammonium sulphate might prove superior.

(*b*) *Broadcasting* vs. *drilling*. In regard to the method of application, neither fertility nor rainfall showed any evidence of association with the difference between broadcasting and drilling in the case of either form of nitrogen in the regression analysis in Table IV. For ammonium sulphate the average difference between the two methods over all trials was negligible and when the trials were grouped according to fertility in Table V, the mean difference was small and not significant for any group. It would thus seem that for ammonium sulphate broadcasting is as good as drilling and would be preferred to the latter on account of its simplicity and saving of labour. With groundnut cake, there was an indication of a slight superiority of drilling over broadcasting both from the average difference over all trials as also from the differences for the three fertility groups in Table V. It would be seen that difference in favour of drilling tended to increase with the soil fertility and in the high fertility group the difference was very nearly significant. Groundnut cake when broadcast has been observed to affect the stand of the crop adversely and the stand is better when the cake is drilled in a furrow at a short distance from the seed furrow. It may be concluded that drilling the cake is a safer practice than broadcasting it and the former method might prove definitely more advantageous on land of high fertility.

(*c*) *Response to nitrogen*. In regard to the relationship between quantity of nitrogen and increase in yield or the response curve, all three regression analyses brought out the dominant role played by soil fertility in determining the rate of response to nitrogen and the linear and quadratic coefficients in Table V and the corresponding response curves in Fig. 2 for the three levels of fertility demonstrate the nature of the difference. One aspect of this difference is that the average rate of increase in yield per unit quantity of nitrogen was larger on land of higher fertility. This means that the same quantity of nitrogen will bring about a larger increase in yield if applied to more fertile land than to poor land. In the low fertility group the average rate of increase in yield per unit application was small. It was over twice as high in the medium fertility group, while in the high fertility group was double of that in the medium group. The significance of the change in the quadratic co-efficient in relation to fertility is similar. The curvature of the response curve or the fall in response to larger doses of nitrogen is less on more fertile land. Consequently large quantities of nitrogen may be more profitably applied under conditions of high fertility than under conditions of medium or low fertility. These points were well brought out by an examination of the response curves of individual trials. Under conditions of high yield as represented by trials in good fields at Jalgaon, Akola, Koilpatti, etc., the response curves were virtually straight lines with small and non-significant quadratic coefficients even when dressings as large as 100 lb. nitrogen per acre were included in the trials. In other words, in such cases the increase in yield was proportional to the quantity of nitrogen even for such large doses. On land of lower fertility the curves bent downwards rapidly, as in trials at Latur, Akola and Nanded in the medium fertility group indicating a rapid

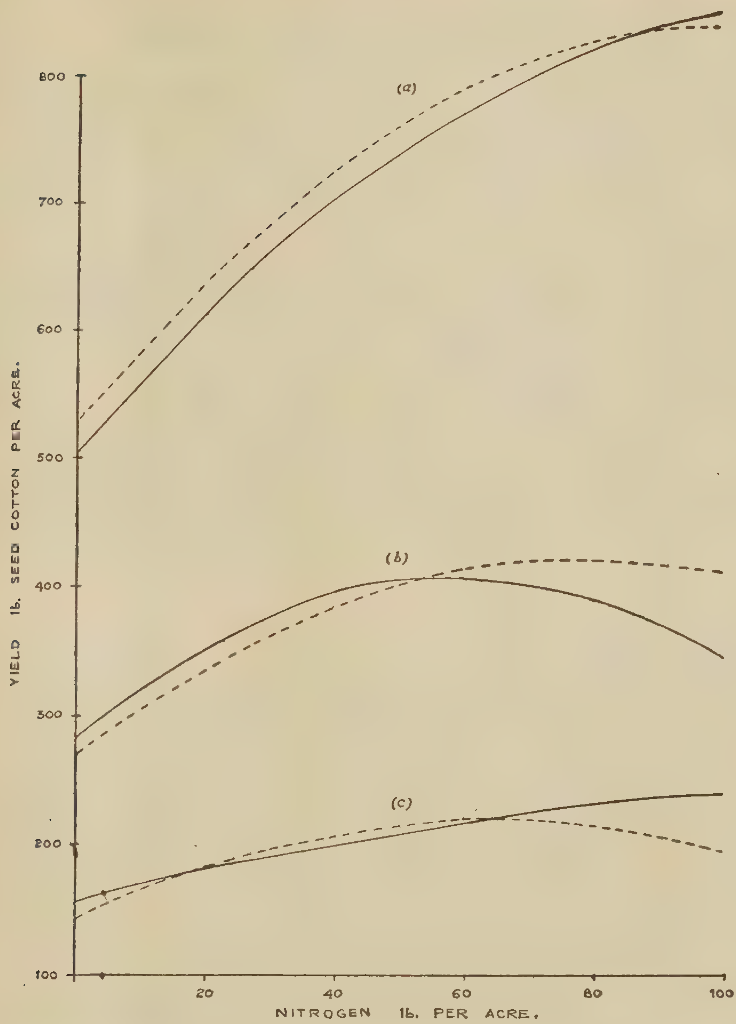

FIG. 2. Comparison of yield curves for three fertility levels derived from separate equations(....) and from a common equation (......).
(*a*) high fertility, (*b*) medium fertility, (*c*) low fertility.

falling off of response with higher doses of nitrogen, or had initially a poor slope as in trials at Indore, Nandayl and Akola in the poor fertility group, which meant that the average rate of increase in yield was low.

The important role played by soil fertility in determining the course of the response curve for nitrogen was thus brought out by the regression analysis and is demonstrated by the typical curves calculated for three fertility levels shown in Fig. 2. It was consequently considered desirable that a general equation for the response curve should be developed which would be capable of giving the appropriate curve at any desired level of soil fertility by substituting in it the numerical measure for the given fertility level. From such an equation, the increase in yield to be expected from a given dressing of nitrogen as also the optimum or most profitable dressing of nitrogen at any particular level of fertility can be calculated easily. With the help of this equation, the study of the economics of manuring could thus be related to soil fertility. This problem is discussed in economics of manuring.

(*d*) *Influence of rainfall.* Influence of rainfall on any of the factors discussed above was not evident from the regression analysis except possibly on the linear coefficient of the response curve as shown by the analysis between years within stations in Table IV. Heavier rainfall had the effect of decreasing the rate of response to nitrogen. The general lack of the influence of rainfall on other factors may be explained partly by the fact that the rainfall was generally adequate and had a relatively narrow variation among the stations selected for the experiments during the years in which the trials were in progress and partly by the possibility, mentioned earlier, that the distribution of rainfall over the season is more important than the annual total.

Adjustment for stand

Before studying the problem of the economics of manuring, the possibility of the increase in yield due to manuring being affected by differences in stand between the manured and unmanured plots was examined. For this purpose, arrangements had been made for recording a final stand count per plot in all trials and out of the 70 trials included in the present study, these counts were available for 61 trials.

Out of the 61 trials, differences in stand for any of the treatments were significant in 24 trials. In these 24 trials, the manured plots had on the average a stand equal to 93 per cent of the unmanured control. Plots treated with groundnut cake had a slightly lower stand than those with ammonium sulphate. In both manures, stand was apparently better conserved by broadcasting than by drilling the manure, but this effect was at least partly ascribable to the faulty method of drilling employed in the earlier trials, *viz.* drilling the manure in close contact of the seed. This effect was particularly noticeable with groundnut cake and in some of the later trials in which the cake was applied in a separate furrow at some distance from the seed furrow, the stand by drilling was better than by broadcasting the cake. The analysis of variance for yield and the mean yields for different treatments were adjusted for covariance between yield and stand by the usual procedure of the analysis of covariance in each of the 61 trials. It was noticed that the adjustment had the effect of slightly lowering the yields of no manure plots and of increasing the yields

of manured plots. Response curves were fitted to the adjusted yields as well as to crude or unadjusted yields. Yields in these trials and average curves for both adjusted and unadjusted yields were calculated for the three fertility levels after grouping the trials in the manner explained earlier. The two types of curves are shown in Fig. 3 and agree so closely as to lead to the conclusion that the disturbance in stand resulting from the application of manure did not produce any significant effect on the course of the response of yield to nitrogen. This conclusion has enabled the present study to be based on the original unadjusted yield data throughout without the results being vitiated by the influence of differences in stand.

Economics of manuring

The importance of planning manurial trials in such a way as to provide adequate data for studying the economics of manuring has been emphasized in the review of the past trials [Panse, 1915] and the present series was planned with this object in view. The results discussed above have clearly shown the necessity of studying this problem in relation to soil fertility, since this factor has been shown to have a profound influence on the rate of response to nitrogen and would have a corresponding effect on the economics of manuring.

The statistical procedure by which response curves can be employed in the study of the economics of manuring has been explained in the review. The expected yield of seed cotton in lb. per acre corresponding to a given dose of nitrogen x, is given by the following equation for the response curve,

$$Y = a + bx + cx^2$$

where a is the yield of seed cotton per acre without application of nitrogen and $bx + cx^2$ is the increase in yield or response expected from the application of x lb. nitrogen per acre. If p represents the price per lb. of seed cotton, the additional money return per acre from the application of x lb. nitrogen would be $p\,(bx + cx^2)$. Further, if q is the cost per lb. of nitrogen, the total cost of manure would be qx and the expected profit would be given by the expression,

$$p\,(bx + cx^2) - qx$$

The dose of nitrogen which would give maximum profit, termed the optimum dose, can be calculated from the expression by differentiating it and then equating to zero. Thus X, the optimum dose of nitrogen, is given by the formula,

$$X = \frac{1}{2c}(q/p - b)$$

Corresponding to any response curve for which the values of the co efficients b and c are known, the optimum dose at varying levels of the ratio

$q/p = \dfrac{\text{cost of nitrogen per lb.}}{\text{price of seed cotton per lb.}}$ can be worked out from this formula. From p e-war data of the cost of ammonium sulphate and groundnut cake and prices of

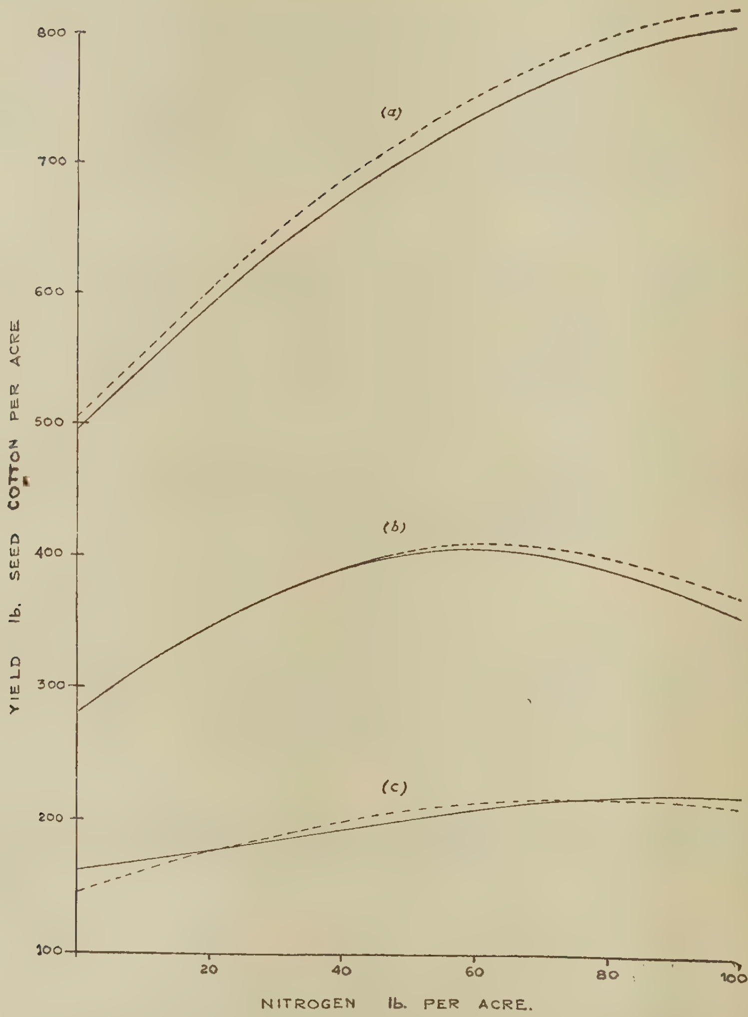

FIG. 3. Comparison between response curves fitted to crude yields (——) and to yields adjusted for stand (......).

(*a*) high fertility, (*b*) medium fertility, (*c*) low fertility.

seed cotton at various experimental farms, this ratio was found to range from 1 or 1·5 to 5·0 [Panse, 1945]. At current rates for the fertilizer and seed cotton, the ratio may be taken to vary from 2·5 to 3·5.

The above method of calculating the optimum dose of nitrogen was applied to the three response curves representing the three fertility groups (Fig. 2) and the results are shown in Table VI.

TABLE VI

Optimum quantity of nitrogen lb. per acre

Fertility group	Ratio q/p = cost of nitrogen per lb. / price of seed cotton per lb.				
	1	2	3	4	5
Low	29	..	..	..	..
Medium	45	31	17	3	..
High	100	79	59	38	17

Assuming the current value of the ratio q/p to be in the neighbourhood of 3 an application of 20 lb. nitrogen per acre to cotton on land of medium fertility and 60 lb. nitrogen per acre on land of high fertility would be expected to be most profitable dressing. On poor land, application of nitrogen would not yield any profit.

This illustration of the influence of soil fertility level on the economics of manuring brought out with the help of response curves appropriate to the three arbitrarily chosen levels of fertility emphasises the value and usefulness of developing a single general equation from which the economics of manuring at any desired level of fertility may be worked out. The approach employed for obtaining such an equation is described below.

The basic equation of the second degree for predicting yield for a given dose of nitrogen from the results of a suitably planned trial is

$$Y = f + B\xi_1 + C\xi_2 \qquad (1)$$

where f is the average yield of the trial and represents a numerical measure of fertility in the sense in which this measure has been defined in the present article; ξ_1 and ξ_2 are first and second degree orthogonal or statistically independent functions of x, the given dose of nitrogen, and B and C are the linear and quadratic regression coefficients of the orthogonal polynomial fitted to the data [Fisher, 1946]. Then Y is the predicted yield per acre for an application of x lb. nitrogen per acre.

Since the regression coefficients B and C in the above equation have been shown to be closely associated with fertility, these coefficients may be replaced by their regression functions in terms of fertility. These functions may be expressed as

$$B'=\bar{B}+b'(f-\bar{f})$$
$$C'=\bar{C}+c'(f-\bar{f})$$

These regression equations were calculated from the data for the 70 trials and gave the following values :

$$B'=0{\cdot}0056\ f-0{\cdot}123$$
$$C'=-0{\cdot}000027\ f-0{\cdot}0134$$

Substituting these values of B' and C' in the equation of the response curve in place of coefficients B and C, we get,

$$Y=f+(0{\cdot}0056\ f-0{\cdot}123)\xi_1+(-0{\cdot}000027\ f-0{\cdot}0134)\xi_2$$

It will be recalled that the number and range of doses of nitrogen used in the different trials were not identical and consequently the values of ξ_1 and ξ_2 were not the same for all trials. The mean values of these functions were therefore calculated over all trials and introduced in the above equation which could then be expressed in the following form

$$Y=-4{\cdot}45+{\cdot}76f+(0{\cdot}0077f+0{\cdot}85)x-(0{\cdot}000027f+0{\cdot}013)x^2$$

This is the prediction formula for yield corresponding to x lb. of nitrogen at the fertility level f. The response to x lb. nitrogen, *i.e.* increase in yield per acre from this quantity of nitrogen, is given by

$$Y'=(0{\cdot}0077f+0{\cdot}85)x-(0{\cdot}000027f+0{\cdot}013)x^2 \qquad (2)$$

The variance of this response is

$$V(Y')=V(B')\bar{\xi}_1^2+V(C')\bar{\xi}_2^2$$

where

$$V(B')=V(\bar{B})+V(b')(f-\bar{f})^2$$
$$V(C')=V(\bar{C})+V(c')(f-\bar{f})^2$$

These variances can be calculated from the regression of B and C on fertility and variances of $\bar{B}$ and $\bar{C}$ are obtained from variation in the values of these coefficients among the 70 trials.

If p is the price of seed cotton per lb. and q is the cost of nitrogen per lb., then as shown previously, the profit to be expected from manuring is given as,

$$p({\cdot}0077f+0{\cdot}85)x-p(0{\cdot}000027f+0{\cdot}013)x^2-qx$$

From this expression, the formula for optimum dose of nitrogen may be derived by maximising it. This formula is

$$X=\frac{q/p-({\cdot}0077f+0{\cdot}85)}{-2\ (0{\cdot}000027f+0{\cdot}013)} \qquad (3)$$

The variance of X or the optimum dose is given by the variance of

$$\frac{q/p-B'}{2C'} \text{ so that } V(X)=\frac{V(B')}{4C'^2}+\frac{(q/p-B')^2}{4C'^4}V(C')$$

We can thus calculate from equation (2) the response to be expected from an application of a given quantity of nitrogen at any particular level of fertility and from (3) the optimum dose of nitrogen corresponding to a desired fertility level. Expressions giving the standard errors of these quantities have also been derived and are shown above. These formulae thus provide logical and unified approach for studying the economics of manuring in place of the results obtained from an arbitrary grouping of the experimental data in different fertility levels.

By substituting various numerical values for x, the dose of nitrogen, and any desired value for f, the fertility measure, in the general formula (2) above, the yield curve corresponding to a particular fertility level can be drawn. From this formula, the values of response in lb. per acre for x=20, 40, 60, 80 and 100 lb. nitrogen per acre and fertility measures=194, 363 and 701 lb. average yield per acre which correspond to the average yields of the trials grouped together in low, medium and high fertility groups made earlier, were calculated and are shown in Table VII. The standard errors of these predicted responses were also calculated and are included in the table.

Table VII

Predicated responses calculated from the general formula in lb. per acre and their standard errors

Fertility measure lb. average yield per acre	Yield without nitrogen	Doses of nitrogen lb. per acre									
		20	s.e.	40	s.e.	60	s.e.	80	s.e.	100	s.e.
194 low fertility	143	40	5·7	66	4·8	77	6·1	72	12·9	54	26·1
363 medium fertility	272	70	4·0	111	3·5	138	4·3	148	9·0	137	18·3
701 high fertility	529	113	5·3	200	4·5	261	5·7	297	12·2	307	24·4

The corresponding yield curves are shown by dotted lines in Fig. 2, where these are superposed on the curves drawn from three separate equations derived from the results of trials grouped under low, medium and high fertility. The agreement between the two sets of curves is sufficiently close to serve as a verification of the soundness of the approach adopted for evolving a single common formula applicable to any chosen level of fertility.

The optimum doses of nitrogen at the three specific fertility levels used in the earlier discussion were also recalculated from the general formula (3) and these values together with their standard errors are given in Table VIII. These values are comparable with corresponding values calculated from three separate response curves for the three fertility groups and shown in Table VI. The two sets of values show a fairly close agreement, as is to be expected. Both tables show that under favourable conditions of prices very high dressings of nitrogen, 80 lb. per acre or more, may be applied with an expectation of maximum profit when the fertility status of the soil is high. At the other extreme, manuring of cotton is not likely to be profitable on poor soil except under the most favourable price conditions.

Table VIII

Optimum doses of nitrogen calculated from the general formula and their standard error

Fertility measure	Ratio q/p — Cost per lb. nitrogen / price per lb. seed cotton									
	1		2		3		4		5	
	Dose	s.e.	Dose	s.e.	Dose	s.e.	Dose	s.e.	Dose	s.e.
194 Low fertility	38	17·3	11	12·3	..	..	..	..	..	..
363 Medium fertility	58	5·7	37	4·1	15	6·3	..	..	..	..
701 High fertility	83	9·2	67	6·6	51	4·6	36	4·0	20	5·3

With the help of the general formulae (2) and (3), tables showing responses to be expected from graded applications of nitrogen on land whose fertility may be represented by an average yield 200, 400, 600, 800 and 1,000 lb. per acre and the optimum doses of nitrogen at these fertility levels have been prepared and are shown in Tables IX and X.

It should be remembered that the numerical values for fertility levels given in these tables correspond to the hypothetical average yield of a trial in which graded doses of nitrogen have been applied and a second degree polynomial fitted to the yields. In making a practical application of the results, however, these average fields will be unknown and will also not be quite appropriate since it is the value of initial fertility represented by yield without the application of the fertilizer that is required for reference. The no manure yields calculated from the respective yield curves are therefore included in these tables side by side with the average yields.

Table IX

Responses, lb. kapas *per acre, expected from graded applications of nitrogen on land with average yield ranging from 200 to 1,000 lb. per acre*

Fertility level lb. *kapas* per acre	No. manure yield lb. *kapas* per acre	Doses of Nitrogen lb. per Acre				
		20	40	60	80	100
200	148	41	66	77	73	55
400	300	69	119	149	161	153
600	452	98	172	224	252	257
800	604	126	224	295	337	351
1,000	756	155	278	369	428	455

The corresponding yield curves are shown in Fig. 4.

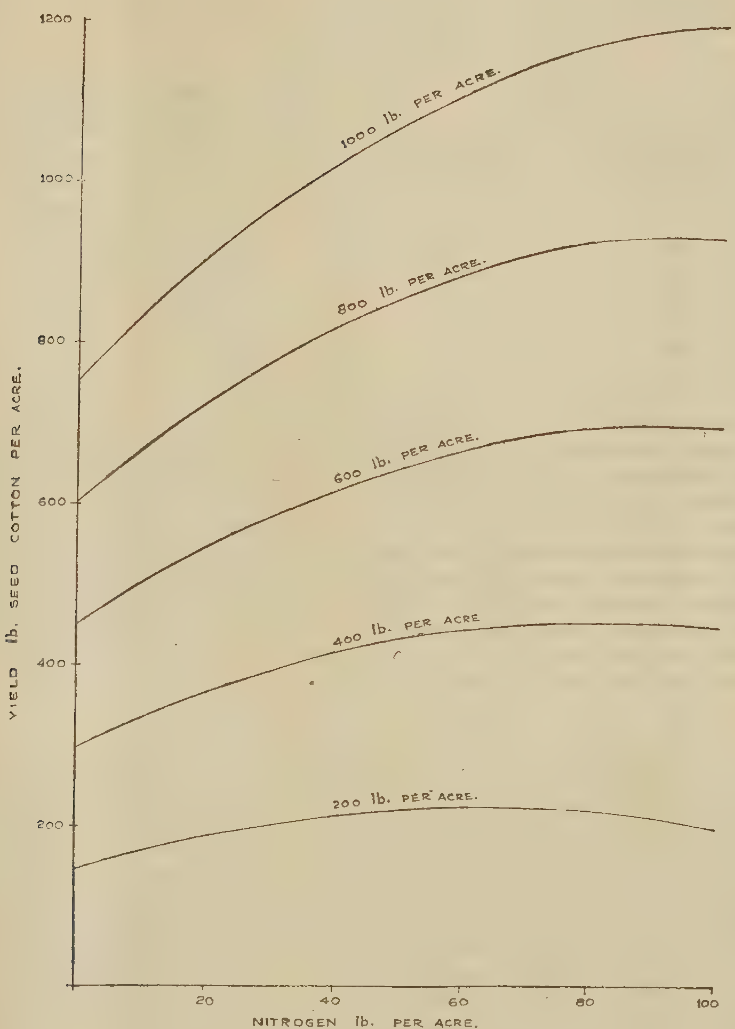

FIG. 4. Yield curves for graded doses of nitrogen at average yield levels ranging from 200 lb. per acre to 1,000 lb. per acre

TABLE X

Optimum doses of nitrogen lb. per acre on land with average yield ranging from 200 to 1,000 lb. per acre

Fertility level lb. *kapas* per acre	No. manure yield, lb. *kapas* per acre	Ratio q/p = cost per lb. nitrogen / price per lb. seed cotton				
		1	2	3	4	5
200	148	38	11	..	..	..
400	300	61	40	19	..	..
600	452	77	60	42	25	8
800	604	86	72	57	43	29
1,000	756	94	82	69	57	44

Under the conditions of soil and climate under which the trials discussed in the present report were carried out, the above two tables should serve as schedules for the manuring of cotton with nitrogen. It would appear from Table X that at current levels of cost of fertilizer and price of seed cotton, giving the ratio q/p in the neighbourhood of 3 as stated earlier, manuring with 20 to 70 lb. per acre of nitrogen on land of medium to high fertility would be expected to give a most profitable return. Manuring of poor land would not be profitable. The verification of these schedules under cultivators' practice is desirable and would be of considerable interest in assessing the practical value of the method employed in the present investigation for analysing the results of manurial trials.

DISCUSSION

For achieving self-sufficiency in our cotton production, increasing the yield per acre would be the means on which we must mainly rely, since extension of cotton acreage has a limited scope and with the existing low yields of crops, the problem of self-sufficiency in different agricultural commodities cannot obviously be solved by extension of cultivation alone. The series of manurial trials, whose results are described in the present article, confirm the earlier findings that in suitable areas, the yield of rainfed cotton can be increased by nitrogenous manuring and further demonstrate that substantial increases in yield, from one to three maunds per acre, can be realized profitably by employing ammonium sulphate or groundnut cake at prescribed rates of application. The condition essential for the successful use of nitrogenous fertilizers and manures on rainfed cotton, *viz.* adequacy of rainfall, exists in several parts of the peninsular India, as in Madhya Bharat, Berar and Nimar district of Madhya Pradesh, parts of Gujerat and East Khandesh district of Bombay State, Nanded district of Hyderabad State and Tinnevelly area of

Madras State, and if fertilizer can be made available for cotton, the results of the present series of trials would provide guidance for its most efficient utilization on rainfed cotton.

The conclusions from the present trials however suffer to some extent from the limitation that these trials were carried out only at Government farms and it would be desirable to test the findings under the cultivators' condition. The fact that the results have been related to soil fertility level is of considerable help in making practical recommendations and it is suggested that agricultural officers may base their recommendations to individual farmers in regard to the dose of nitrogen and other details of manuring on the data given in the present article and record their observations and results in the form of a suitable questionnaire drawn up for this purpose. Such observations will be very useful in assessing the effectiveness of the manure and its profitableness under actual growers' conditions. Secondly, extensive trials with a simple layout, in the manner recommended by Stewart [1947], may be carried out in selected districts. It is, however, suggested that doses of nitrogen to be employed, instead of being uniform over all the trials, may be fixed in accordance with the level of the initial productivity of the experimental field. Two dressings, one in the neighbourhood of its optimum value as calculated from the general formula given here and another at half of the optimum value, may be included in the trial in addition to a no-manure control. The results of such a series of trials would provide valuable information for verifying the present conclusions.

Other manurial investigations that offer possibilities of increasing yield and need to be carried out on a co-ordinated basis, as in the case of the present series of trials, relate to the use of phosphatic fertilizers and manures. Past results have been generally negative and have shown that application of phosphate either alone or in combination with nitrogen did not increase cotton yield. There were exceptions, as for example at Koilpatti in Madras where phosphate appeared to be a useful manurial constituent. The general lack of response to phosphate may be due partly to the low level of nitrogen at which phosphate was tried ; but if nitrogenous manuring of cotton is to become a widespread practice and is to maintain its effectiveness, care will have to be taken of the availability of phosphate from the soil, since unless the available amount of phosphate in the soil is replenished, this might tend to become a limiting factor in the response of cotton to nitrogen in the course of time. Secondly, as Stewart [1947] has emphasised in his report, the general immobility of phosphate in the soil and consequent need of its deep placement in the soil at an early stage does not seem to have been appreciated in the past. The broadcast dressings of phosphate on the surface of the field would thus be ineffective and particularly for a deep rooted crop like cotton, deep application of phosphate has to be studied before any generalization can be made regarding its usefulness or otherwise.

Another promising line of investigation in connection with the phosphatic manuring of cotton is the application of phosphate to leguminous crops preceding cotton. Experimental work in Madhya Pradesh, Bombay and Hyderabad has established the value of groundnut as e rotation crop for cotton and the yield of cotton after

groundnut has been found to be appreciably higher than after *jowar* or other millets which are the traditional rotation crops for cotton in rainfed areas of peninsular India. Secondly, work done at the Indian Agricultural Research Institute has shown that legumes like berseem not only respond to phosphatic manuring themselves; but the beneficial effect of the application persists in the next crop as well. These results indicate the value of a trial of various leguminous crops as rotation crops for cotton and the effect on cotton of the phosphatic manuring of the preceding leguminous crops. Following the success of the present co-operative investigation on the nitrogenous manuring of cotton, it is hoped that other investigations aimed at increasing the yield of cotton per acre will be taken up on the same plan.

Summary

In pursuance of the recommendations of the Indian Central Cotton Committee, a series of co-ordinated manurial trials on rainfed cotton were carried out during the period 1943-44 to 1947-48, on black soil at 15 experimental farms in different states in peninsular India. Out of a total of 89 trials, the results of 70 trials, after omitting the rest which did not satisfy the necessary conditions of soil and rainfall, were subjected to a comprehensive statistical analysis and the conclusions derived from this analysis are described in the present article.

The problems studied in these trials were: (1) the relative efficiency of nitrogen in the form of ammonium sulphate and groundnut cake; (2) comparison between two methods of applying nitrogen, drilling and broadcasting and (3) the relationship between quantity of nitrogen and increase in yield and the determination of the optimum, or most profitable, quantity of nitrogen for application to cotton. The influence of soil fertility and rainfall on these factors was studied and with the former object the trials were deliberately located simultaneously on two or three fields differing in the level of fertility at each station.

The main conclusions reached may be summarised as follows:—

(1) For equal quantity of nitrogen, there was a little difference between ammonium sulphate and groundnut cake in their effectiveness, except possibly on soil of high fertility where ammonium sulphate was found to be slightly superior to groundnut cake.

(2) The two methods of applying nitrogen, drilling and broadcasting, showed no difference in the response of cotton either for ammonium sulphate or groundnut cake. Broadcasting would thus be the method to be recommended for ammonium sulphate; but drilling might be considered a safer practice for the cake, since it has been observed that the stand of the crop was affected adversely by broadcasting; if the cake is drilled in a furrow at some distance from the seed furrow the stand is better maintained.

(3) Rainfed cotton generally showed a significant response to nitrogen; but soil fertility played a dominant role in determining the rate of response. The rate of increase in yield with a given quantity of nitrogen increased as the initial soil fertility was higher. The close

association between soil fertility and rate of response was taken as the basis for developing prediction formulae, from which can be calculated the increase in yield to be expected from a given dressing of nitrogen on land at a particular level of productivity as also the optimum or most profitable quantity of nitrogen for application under these conditions. Numerical tables giving increases of yield to be expected from different doses of nitrogen and optimum dressings of nitrogen at a range of fertility levels have been prepared. These data might serve as schedules for manuring.

(4) The effect of annual rainfall on the different aspects of manuring was examined but was not brought out, except possibly in relation to the average rate of increase in yield from the application of a given quantity of nitrogen, which appeared to decrease with higher rainfall. The generally non-significant results with rainfall may be partly ascribed to the fact that the trials were grown under a relatively narrow variation of annual rainfall which was on the whole adequate and partly to the possibility that under these conditions the distribution of rainfall over the season is more important than the annual total.

The results of the present series of trials have confirmed the earlier findings that yield of rainfed cotton can be increased by nitrogenous manuring and have further amplified the specific conditions under which such manuring can be profitably employed. Further work needed for utilizing the present results in practice and for investigating other manuring possibilities for increasing cotton yield have been discussed in the article.

Acknowledgments

Fifteen experimental farms in Bombay, Madhya Pradesh, Madhya Bharat, Hyderabad and Madras participated in the present project. The whole-hearted co-operation received from the Directors of Agriculture concerned in providing facilities for the conduct of the trials and from the Research Officers at the different stations in carrying out the trials according to an agreed plan is acknowledged here. Acknowledgment is also made to the Indian Central Cotton Committee for providing financial assistance for the comprehensive statistical analysis of the results of these trials.

REFERENCES

Fisher, R. A. (1946). *Statistical Methods for Research Workers*, Edinburgh, Oliver and Boyd London, 10th Edition

Panse, V. G. (1945). Manuring of Cotton in India. Indian Central Cotton Committee, Bombay

Stewart, A. B. (1947). *Report on Soil Fertility Investigations in India with Special Reference to Manuring*, Indian Council of Agricultural Research, New Delhi

Sukhatme, P. V. (1941). *Economic of Manuring*. *Indian J. agric. Sci.*, 11, 325

Yates, F. (1935). Discussion on *Statistical Problems in Agricultural Experimentation* by J. Neyman, *Supp. Jour. Roy. Stat. Soc.*, 2, 107

An exparimental 3-trukey unit tunnel dehydrator (re-circulating, air-blast type) for dehydration of fruits and vegetables.

*SOME STUDIES IN THE PRESERVATION OF FRUITS AND VEGETABLES

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(With Plate IX)

ON June, 1st 1941, a scheme under the style of ' Scheme for Special Work on Fruit and Vegetable Preservation ' was started by the Indian Council of Agricultural Research at Lyallpur (now in West Pakistan) to help in the war effort by undertaking in its laboratory the testing of foodstuffs (especially fruit and vegetable products), i.e., development samples received from the Supply Department from time to time, in accordance with the R.I.A.S.C. specifications. The object of these tests was to serve a dual purpose, firstly to discover defects in their manufacture and the detection of factitious samples as distinct from genuine ones and secondly to advise on the improvement of quality when discovered to be poor. In addition, research problems which were of immediate benefit to the Supply Department were also expected to be attended to by the staff of this scheme.

The scheme continued to work for the Supply Department upto 31 March, 1943 after which the scheme worked upto 31 March, 1945 for the benefit of the Fruit and Vegetable Preservation Industry of the country as a whole. During the tenure of this scheme, a number of important research problems were tackled both for the benefit of the Supply Department and Industry. The present article gives briefly the results of practical importance achieved in respect of these investigations and it is hoped that the information given will serve a useful purpose.

INVESTIGATIONS

I. *Dehydration of fruits and vegetables*

Dehydration of Vegetables.

Construction and standardization of a dehydrator. An experimental three-trolley unit tunnel dehydrator of recirculation air-type was installed in 1941 and is illustrated in Plate IX. As no working plans of the dehydrator were available, a good deal of time was spent in its construction. The various parts had to be dismantled and remodelled several times before ideal conditions of temperature, humidity and air flow for proper working could be obtained. The finally standardized dehydrator consisted of a drying chamber (13 ft.×5 ft.×6 ft.) at the top of which were housed the heating and fan chambers. A multiblade blower type fan (20 inches

*Results of practical importance achieved under the scheme for special work on Fruit and Vegetable Preservation, Lyallpur (Punjab).

TABLE I

Methods of dehydration of vegetables as standardized in an experimental tunnel dehydrator at Lyallpur

Serial number	Name of vegetable	Preparation	Treatments before drying	Lb. of prepared vegetable per sq. ft. of tray surface	Drying temperature at ' cold end'	Drying temperature at ' hot end '	Drying time (hours)	Drying ratios Unprepared	Drying ratios Prepared
1	Bitter gourd (*Karelas*)	Peel by scraping thoroughly and cut into ¼ in. thick slices	Blanch for 7 to 8 minutes in boiling water	1·0 to 1·25	150°F.	160°F.	7—9	26 : 1	15 : 1
2	Brinjals*	Peel thinly with sharp knives and cut into ¼ in. thick slices	Immerse the slices for 1½ hours in 0·5 per cent SO_2 solution and then blanch in boiling water for 4 to 5 minutes	1·0 to 1·5	120°F.	130°F.	9—11	33 : 1	20 : 1
3	Cabbage	Remove outer leaves and cores; shred into 3/16 in. thick shreds	(*a*) Steam for 5 to 10 minutes or (*b*) Blanch for 2 to 3 minutes in boiling 1·0 per cent soda-bicarb solution	1·5 to 2·0	140°F.	150°F.	12—14	18 : 1	15 : 1
4	Carrots	Peel by scraping, cut stalks and tips and slice into 3/16 in. thick slices	Blanch for 2 to 4 minutes in boiling 2 per cent common salt solution	1·0 to 1·5	155°F.	165°F.	14—16	18 : 1	16 : 1
5	Cauliflower	Remove stalks, covering leaves and stems; break apart the flowers and cut them to suitable size	Blanch in water for 4 to 5 minutes; steep in 0·5 per cent SO_2 solution for ¾ to 1 hour and wash gently	1·0 to 1·5	140°F.	150°F.	10—12	35: 1	18 : 1
6	Knol Khol	Remove stems, peel thoroughly and cut into 3/16 in. thick slices	(*a*) Dry as such, or (*b*) Immerse for 30 to 45 minutes in 0·25 per cent SO_2 solution and wash	1·0 to 1·5	130°F.	140°F.	11—13	19 : 1	11 : 1
7	*Methi* (Fenu-greek)	Remove foreign leaves by sorting and rotten portions by trimming	(*a*) Steam for 6 to 10 minutes or (*b*) Blanch in 2 per cent common salt solution for 15 seconds	¾ to 1·0	140°F.	150°F.	10—12	17 : 1	9: 1
8	Okra	Remove stalks and tips and cut cross-wise into ½ in. thick pieces	Blanch in boiling water for 4 to 8 minutes	1·0 to 1·5	145°F.	155°F.	6—8	12 : 1	9 : 1
9	Onions	Trim and peel to remove outer dry leaves; slice into 1/16 in. thick shreds	Treat the shreds in 5·0 per cent common salt solution for 10 minutes and drain	0·75 to 1·5	140°F.	150°F.	11—13	10 : 1	8 : 1
10	Potatoes	Peel and slice into 3/16 in. to ¼ in. thick slices	Blanch in boiling water for 3 to 5 minutes and cool immediately in running cold water	1·0 to 1·5	140°F.	150°F.	7—8	7 : 1	8 : 1
11	Pumpkin (*Halwa kadu*)	Cut into about 2 in. wide longitudinal strips: peel thoroughly, remove seeds and soft portions in contact with seeds and cut the strips into ¼ in. thick slices	Keep the peeled strips as well as slices in 2 per cent salt solution and then (*a*) steam the slices for 10 to 20 minutes, or (*b*) blanch in 2 per cent common salt solution	1·0 to 1·5	150°F.	160°F.	9—11	19 : 1	13 : 1
12	Radish (*muli*)	Remove stalks, peel thinly and cut into 3/16 in. thick slices	(*a*) Immerse for 1 to 1½ hours in 0·5 per cent SO_2 solution or (*b*) blanch in water for 6 to 7 minutes, sulphur as in (*a*), wash and dry	1·0 to 1·5	145°F.	150°F.	10—12	30 : 1	24 : 1
13	Spinach	Sort, trim and wash thoroughly in running cold water	(*a*) Dry the washed product as such, or (*b*) steam for 4 to 5 minutes	0·75 to 1·0	145°F.	155°F.	7—8	22 : 1	16 : 1
14	Squash (*ghiu kadu*)	Peel, cut into 4 segments which should be sliced into ¼ in. thick slices	Treat for about half an hour in 2 per cent common salt solution and then— (*a*) steam for 10 to 20 minutes or (*b*) blanch in 2 per cent common salt solution	1·0 to 1·5	150°F.	160°F.	9—11	22 : 1	21 : 1
15	Tomatoes	(*a*) Peel by scalding in boiling water for 30 to 60 seconds, cut into ¼ in. to ⅜ in. thick slices with sharp knives, or (*b*) for powdering, slice without peeling	Dry the slices without any treatment	1·0 to 1·5	140°F.	150°F.	9—10	27 : 1	25 : 1
16	Turnips	Peel, remove stalks and cut into 3/16 in. thick slices	Immerse for 1 to 2 hours in 0·5 per cent SO_2 solution, wash and then— (*a*) blanch in water for 2 to 4 minutes, or (*b*) steam for 10 to 12 minutes	1·0 to 1·5	125°F.	135°F.	11—13	28 : 1	19 : 1

NOTE*.—The prepared brinjal slices should not at any stage be allowed to come in contact with iron, especially during blanching and drying.

NOTES.—1. Wash the vegetables thoroughly to remove dirt and other sticking matter before handling.
2. Maintain the Humidity in the dehydrator as under: Cold end—40 to 45 per cent. Hot end—20 to 25 per cent.
3. Under the heading 'treatments before drying', in some cases alternative methods have been given. In such cases, the quality of the dried vegetables obtained by these alternative methods was almost similar.

in diameter with 12 blades) in the fan chamber ($2\frac{1}{2}$ ft. $\times$ 5 ft. $\times$ 7 ft.) blew air over the heating coils (of about 80 square feet surface area) fixed in the heating chamber which had a connecting passage on one side to the fan chamber and on the other to the drying chamber. Adequate devices for the controlling of humidity, temperature and air flow were provided in the dehydrator. The dehydrator had a small rail track with necessary turn-tables which provided a continuous feeding of the dehydrator with trollies loaded with prepared vegetables.

Complete working plans of the dehydrator were supplied to the Supply Department on request and it is understood that these plans were kept as a basis by this Department for the construction of commercial dehydrators all over the country which worked for supplying dehydrated vegetables to this Department.

Standardization of the methods of dehydration of vegetables. Methods for the dehydration of different summer and winter vegetables (16 in number) were evolved by exhaustive experimentation in these laboratories. This involved the standardization of the method of preparation of each vegetable, its treatment prior to drying, times and temperatures of drying, etc. The methods finally standardized and tested for the dehydration of 16 vegetables on a semi-commercial scale in the tunnel dehydrator are briefly presented in Table I which is self-explanatory. Complete details of the methods of dehydration of various vegetables, were supplied to the Supply Department to serve as a guide for the prospective manufacturers.

Spoilage of cut and prepared potato slices, in case of accidental breakdowns of the dehydration plant, could be successfully prevented by steeping them in a 0·035 per cent solution of sulphur dioxide.

Varietal trials on dehydration of potatoes. Sixteen important varieties of potatoes grown in the hills and plains of the United Provinces, Punjab and Madras, were tested for their suitability for dehydration ; results were as under :

(i) *Varieties yielding standard quality dehydrated product*

1. *Gola* 2. *Chambared* 3. U.S.A. No. 1 4. U.S.A. No. 3 5. Factor	Punjab varieties
6. *Metropoleum* 7. *Gola* 8. *Majestic*	United Provinces varieties

(ii) *Varieties yielding a fair quality dehydrated product*

1. *Surkha* 2. Kangra local 3. Italian white	Punjab varieties
4. Great scot	Madras variety
5. *Phulwa*	United Provinces variety

(iii) *Varieties not suitable for dehydration*

1. U.S.A. No. 7	Punjab variety
2. *Desi* 3. *Patna*	United Provinces varieties

Preparation of briquettes of dried vegetables. All dried vegetables could be successfully converted into 5 in.×$\frac{3}{4}$ in. round briquettes (weighing 12 to 14 oz.) by pressing in a hydraulic press, using a special die.

Storage of dried vegetables. For storage of all the dehydrated vegetables, the best conditions were found only in hermetically sealed packings, though potatoes could be safely stored even in reasonably air-tight containers like friction top tins.

Cost of production of dehydrated vegetables. Cost of production of all the vegetables mentioned in Table I was worked out on the basis of semi-commercial trials in the tunnel dehydrator giving details of labour, raw material, running charges of the dehydrator, etc. The entire data thus collected were sent to the Supply Department and proved of great use to this department in fixing of contract rates for dehydrated vegetables.

Vitamins in dried vegetables. Vitamin C (ascorbic acid) of the fresh vegetables suffered an appreciable loss during the process of drying of vegetables; carotene (vitamin A) on the other hand, proved much more stable. Retension of ascorbic acid was, in general, more in case of vegetables cooked in steam at 10 lb. pressure, prior to drying; than in those blanched as usual in boiling water, before drying. General quality of the dried vegetables was, however, better when dried after blanching than after cooking in steam. The losses of both the vitamins were, in general, more during sun drying than during dehydration.

Dehydration of fruits.

Dehydration of amla (Emblic—Phyllanthus emblica). A method standardized for dehydration of *amla* consists of blanching the fruit in 2 per cent common salt solution for about 7 minutes, followed by dehydration at 140 to 145°F.

Reprocessing of Afghan dried fruits. Dried fruits such as apricots, figs and raisins (red, green and black) received in the market from Afghanistan, were usually of very poor quality. Supply Department consequently experienced great difficulty in the purchase of these fruits. This investigation, for the reprocessing of dried fruits was, therefore undertaken with two broad lines of work in view. Firstly, the improvement of colour and general appearance and keeping quality by sulphuring and secondly the removal of diseased berries and also grit and other extraneous matter. On the basis of experiments carried out, the following method for reprocessing was finally evolved and standardized:

(i) Wash the fruits thoroughly but gently in running cold water for about 5 minutes. (This period of washing was found to be the best both from the point of absorbing SO_2 as well as leaching out of reasonably small quantities of sugar. This also removed most of the extraneous matter like sand, stems, etc.).

(ii) Drain off the water and spread the fruit on wooden slate bottom trays.

(iii) Place the fruit immediately in sulphur chamber for sulphuring. Burn the required amount of sulphur as per dose given below and let the fruit be in contact with the SO_2 fumes for the recommended period.

Fruit	Amount of sulphur burnt	Time of exposure to SO_2 fumes
Apricots	16 lb. per ton of fruit per 1,000 c.ft. of chamber	3 hours
Figs	Ditto	2 „
Black raisins	8 lb. per ton of fruit per 1,000 c.ft. of chamber	4 „
Green raisins	Ditto	1 „
Red raisins	4 lb. per ton of fruit per 1,000 c.ft. chamber	1 „

(iv) Dehydrate the fruit after sulphuring, at a temperature of 150°F. to 155°F. (Time taken for dehydration in a home-drier varied from 3 to 4 hours.)

(v) After drying, remove the remaining stems in case of raisins; discard damaged fruits and pack the final reprocessed stuff in fairly air-tight and moisture proof containers, such as friction top or soldered top tins.

II. *Canning*

Canning trials on fruits. Canning trials on 32 different varieties collectively, of plum, peach, apricot and pear, grown in the United Provinces (Chaubattia—Kumaon Hills, and Saharanpur) Kashmir and the Punjab (Palampur) were carried out with a view to select the best canning varieties of these fruits grown in these parts of the country, as it is well known that all varieties of a particular fruit are not suitable for canning. The canned product obtained in each case was tested over a storage period of about two years. As a result of these tests (of a tentative nature) the following varieties of different fruits were found suitable for canning:

Fruit	*Varieties with source of origin*
Plums	Ladak *Alubukhara* (plum). Large, Howe and Kelsey's Japan (Saharanpur—United Provinces) Yellow prune and Satsuma (Kashmir) Merriposa, Chabot and Satsuma (Palampur—Punjab).
Peaches	'Quetta' variety (Kashmir) and Fitzgerald (Chaubattia—United Provinces).
Apricots	Charmagaz (Quetta—Baluchistan), obtained from local market.
Pears	'Williams' (Kashmir).

There was in general no marked difference in the quality of the products canned in plain and lacquered cans, except that colour retention in case of plums was better in lacquered than in plain cans. The former however suffered from pin-holing which was observed after 7 to 9 months storage in case of plums and 12 months in case of apricots and peaches.

Canning of black berries.

'Himalaya' variety of black-berries grown at Palampur (Punjab) yielded a product of an excellent quality when canned in 45° Brix syrup, employing 6 minutes 'exhaust at 180 to 190°F. and 90 minutes' sterilization in boiling water (A_2 size cans). Lacquered cans proved satisfactory and the product kept well for over a year.

Canning of citrus fruits (malta and sangtra).

Investigations on canning of oranges, were undertaken on behalf of the trade, in order originally to standardise a method for the purpose; but were later extended to the testing of important varieties with regard to their canning qualities as also to the use of canned oranges in the preparation and canning of fruit salads. In preliminary experiments, method of peeling the segments, and processing times, etc., were standardized. The method finally evolved and standardised for canning of oranges both on a small as well as large scale, as a result of experiments carried out in this direction, is given below. The canned product prepared by this method was tested over a storage period of over two years and found to keep very well in all respects. It was greatly liked and highly spoken of by various important fruit preservers of the country, including Mr. R. Mitchel of Indian Mildura Fruit Farms, Ltd., Renala Khurd (now in West Pakistan).

Method for the canning of oranges (malta and sangtra)

(i) Peel off the oranges to remove the outer skin (peel) and separate the segments with hand.

(ii) Treat the segments in 2·0 per cent boiling lye (sodium hydroxide solution) for 25 to 30 seconds; after this put immediately in cold water to cool them and wash off the excess of lye. During this process of cooling and washing, remove the cauterized peels (i.e., thin membrane enclosing the orange sections), sticking fibre and rag portions as well as seeds, by gently rubbing the segments with hand. Deeply imbedded seeds may be conveniently removed with the help of stainless steel forceps.

(iii) Rinse the peeled segments in 2·0 per cent citric acid solution; followed by a thorough wash in cold water, and simultaneously also remove the sticking peel pieces if any on the surface of the segments.

(iv) Finally pass the peeled segments through another change of water so as to thoroughly wash off any peel pieces or traces of acid present. After this, drain on a sieve of some non-corrodible metal.

(v) Fill the peeled segments obtained as above in A2 plain tin cans at the rate of about 1 lb. in each can and cover them with 55° Brix hot sugar syrup. For fortification of flavour, essence 'vita crush' may be added to the syrup @ 1 oz. (weight) per 4·5 gallons, after heating the syrup.

(vi) Exhaust the cans at 175 to 185°F. for 20 minutes, seal them air-tight in a double seamer, sterilize at 180 to 185°F. for half an hour and finally cool in running cold water as usual.

Varietal trials. Varietal trials carried out with four important varieties of malta, viz. blood red, common, Jaffa and pineapple; and two of *sangtra* viz. *desi*

and *Nagpuri*; revealed that all the four varieties of malta were suitable for canning. Out of the two varieties of *sangtra* tested, *desi* variety yielded a product slightly tart in taste, although both flavour and taste remained unchanged during about two years' storage. It was felt that it would perhaps yield a product of better quality, if canned in sugar syrup of a higher concentration say 60 to 65° Brix. Product from Nagpuri *sangtra* was rather sweet but possessed good flavour which remained unchanged for over one year.

Use of canned oranges in the preparation of fruit salads. Canned orange segments were found to give a very good quality fruit salad when recanned in combination with William's pears, in the ratio of 2 : 1 or 1 : 1; employing 40° Brix canning syrup (prepared by the addition of appropriate quantities of sugar and water to the covering syrup of canned oranges), 8 minutes' exhaust at 180-190°F. (for A $2\frac{1}{2}$ cans) and sterilization for half an hour in boiling water. The product also showed a very good storage behaviour during tests carried out over a period of over one year.

Formation of hydrogen swells in canned fruits

The object of this investigation was to study the causes of formation of hydrogen swells in canned fruits and to find out remedial measures to avert or minimise this type of spoilage especially during storage under field conditions. The fruits selected for this study were the most commonly canned ones, viz. plums, peaches, apricots and tomatoes. The investigation was extended over a period of two years and involved thorough physico-chemical analysis and general examination and cut-out tests of a total of over 1,200 cans of various fruits, canned under different treatments and stored under different conditions. Results of these tests are presented in Table II from which the following conclusions were arrived at :

(i) Hydrogen swells in cans appeared 15 and 17 months after canning fruits, under Punjab conditions of storage, outdoor and indoor respectively.

(ii) Roof stored cans showed higher swell as compared with laboratory stored ones.

(iii) Plain cans showed less swell than lacquered, whereas scratched lacquer cans showed the maximum swell.

(iv) Of the four fruits tested, the increasing order of swell formation was as : Tomatoes, peaches apricots, plums, irrespective of temperature of storage or type of cans used.

(v) Addition of 0·5 to 1·0 per cent citric acid to 40° Brix canning syrup retarded swell formation in peaches, but accelerated in case of apricots and plums.

(vi) Use of plain cans and 40° Brix plain canning syrup appeared to be best for apricots and plums although there was loss in colour of the fruits especially in plums canned in plain cans as compared with lacquered. However the loss in colour may be overlooked as the percentage loss in plums canned in lacquered cans was very high as compared with plain ones.

TABLE II

Percentage of hydrogen swell in different types of cans with different internal treatments to canning syrup (at two storage temperatures) during a storage period of about 24 months

Internal treatment of syrup	Tomatoes						Peaches						Apricots						Plums					
	Laboratory stored			Roof stored			Laboratory stored			Roof stored			Laboratory stored			Roof stored			Laboratory stored			Roof stored		
	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC	P.	L.	SLC
A	0	0	0	0	0	10	10	8	0	10	0	9	0	0	9	0	0	0	0	9	27	0	18	4
B	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	24	8	16	0	18	27	0	25	3
C	—	—	—	—	—	—	0	0	0	0	9	0	18	0	9	8	0	0	14	6	18	0	30	3
D	—	—	—	—	—	—	0	0	18	0	9	9	0	10	0	0	45	6	27	16	17	0	40	0

Treatments : A = Fruit in 40° Brix sugar syrup alone.
B = Fruit in 40° Brix sugar syrup alone plus 0·5 per cent added citric acid.
C = Fruit in 40° Brix sugar syrup alone plus 1·0 per cent added citric acid.
D = Fruit in 55° Brix sugar syrup alone.

In the case of tomatoes, treatment A = Canned with sugar and salt (solid pack).
B = Canned without sugar and salt (solid pack).

P—Plain cans
L—Lacquered Cans
SLC—Scratched lacquer cans

Canning of plums in lacquered cans. In the light of the above results, further experiments carried out with plums revealed that use of 35° Brix canning syrup containing 0·042 per cent added agar, or 2·0 per cent brown sugar, helped considerably to reduce the incidence of swell formation in plums canned in lacquered cans.

Suitability of black steel plate cans for packing various food products

Different types of cans made out of black steel plate and lacquered inside with different lacquers were tested for their suitability for packing food products like fruits, jams, golden syrup, butter, hydrogenated oil, etc. One type of these cans were lacquered in these laboratories with a special food lacquer obtained from the Director of Indian Lac Research Institute. The details of the technique of applying the lacquer were also developed here and the lacquer found quite suitable for the purpose.

Fruit products. Three types of lacquered black steel plate cans were tested for packing fruit products. Due to certain defects in the closure of these cans (as proper machinery for fabrication of these cans was not available with Messrs. The Metal Box Co. of India Ltd.) they were found to be unsuitable for canning of fruits, but were, however, found quite suitable for jams, jelly and marmalade. No significant adverse change was noticed in the quality of peach and apricot jams guava jelly and orange marmalade (except slight change in colour) packed in these cans, upto a storage period of one year in general. Some of these produts in certain types of cans, could, however, be safely stored even for a longer period. The cans showed only slight corrosion of the lacquer followed by slight rusting in some cases.

Other products. Two samples of golden syrup, two of butter and one of hydrogenated oil, packed in different types of lacquered black steel plate cans were obtained from local factories manufacturing these products. These were tested and analysed physically, chemically and bacteriologically during a storage period of about 6 months in case of golden syrup and butter and one month in case of hydrogenated oil. The result obtained showed that packing of golden syrup and hydrogenated oil in these cans was fairly safe as the products did not show any significant chemical changes. The cans used for butter, also did not impart any adverse change to the palatability, flavour and colour of butter during the storage period studied.

III. *Jams*

Prevention of mould growth on the surface of jams and marmalade in jars lacking air-tight seal. Due to scarcity of rubber seals for jam jars during war time, the manufacturers encountered a great deal of difficulty in packing of these products. As a result of experiments carried out in solving this problem the following methods were found successful in preventing spoilage of these products (packed in non-air-tight screw cap jars) due to mould growth.

(i) A layer of molten paraffin wax (high melting point, about 53°C.) put on the surface of jam.

(ii) Tissue paper dipped in molten paraffin wax put over the surface of jam, after cooling it in the jars for 3½ hours.

(iii) A layer of invert sugar syrup put over the surface of jam after cooling it for 3½ hours or over-night; but this is not practicable commercially. Layers of glycerine and liquid paraffin also prevented mould growth but not bacterial contamination.

IV. *Juices and squashes*

Preservation of natural lime juice.

With a view to find out the best method of preserving purelime juice for maximum retention of vitamin C (ascorbic acid) three methods were tried; viz. addition of SO_2 to the juice 'as such'; addition of SO_2 after de-aeration of juice; and de-aeration followed by 'flash' pasteurization. The last method showed minimum percentage loss of ascorbic acid during storage while the first one showed the maximum. During packing of the juice there was practically no loss due to de-aeration, but 'flash' pasteurization caused slight loss.

Quicker sedimentation of lime juice for cordial making.

The usual sedimentation method practised for the clarification of lime juice in a commercial factory took two to four months, hence need was felt by the trade, since long, for the development of method for quicker sedimentation. A method was evolved for this purpose in these laboratories. This consisted in the gradual addition of solutions of tannin and gelatin (in water) to the lime juice. In a typical laboratory experiment, the dose of tannin and gelatin was at the rate of about 7·5 ounce and one ounce respectively for 550 gallons of juice. The juice in this experiment was completely clarified in about four to six days and no foreign taste or flavour was imparted to the final cordial.

Other methods such as filtration, treatment with activated carbons, kaolin, etc., which were tried, either did not give good results or were too slow.

In testing the applicability of this method to commercial practice, it was found that the clarification of juice was controlled by various factors, such as the method of extraction and pre-treatment of juice, its composition, storage period, etc. It was, therefore, found necessary to determine the dose of tannin and gelatin for each particular lot of juice, by carrying out a small test experiment. With the addition of the appropriate dose of tannin and gelatin (determined by test experiments) vats containing 600 to 1,400 gallons of juice could be successfully clarified in about 10 to 12 days.

This method was given to the trade and was found of immense help for the quick clarification of lime juice in Mr. Mitchel's squash and cordial factory at Renala Khurd, which was one of the biggest cordial making factories in pre-partitioned India. The remarks made by this firm about this method are reproduced below.

'We are greatly indebted to you for giving us this new method which has proved of immense use to us. As we have already pointed out our cordial manufacture would have been seriously delayed if we had not got this method in time. Until now we have to keep large quantities of lime juice in stock and even when extracting new juice we keep about four months' supply of old lime juice as the new juice is supposed to take at least four months to clear up; but with this method we hope to be able to reduce our stocks and make use of the supplies of fresh limes which can be had practically all the year round.'

Distribution of pulp in citrus squashes

The pulp present in citrus squashes has, in general, been found to settle down at the bottom or rise in the neck of the bottles. This pulp in the latter case particularly presents a very unsightly appearance. An investigation was, therefore, undertaken to find out ways and means to keep the pulp in uniform distribution throughout the contents of the bottle.

Lime squash. In experiments carried out in this connection with lime squash, 46 sets were prepared under different treatments, according to the usual formula. As a result of the tests carried out with these sets during a storage period of about $1\frac{1}{2}$ years the following methods were evolved to avoid the collection of pulp in the neck of the bottles.

(i) Heating of the prepared squash for 1 to 4 minutes at 60°C.

(ii) Addition of gum tragacanth (0·05 per cent) or pectin (0·05 per cent) or common salt (0·05 per cent) or gum acacia (0·75 per cent) to the juice before preparing squash, helped to bring the pulp down at the bottom.

(iii) Addition to the juice of water extract prepared from the rag of limes left after juice extraction at the rate of about 25 per cent, also made the pulp settle at the bottom. With increasing amounts of this extract added to the juice, the column of pulp in the bottle could be increased proportionately until with about 75 per cent addition the whole of the pulp distributed uniformly throughout the bottle, thus yielding a permanently cloudy product. (Water to be added in the preparation of the squash was reduced by an amount equal to that of the rag extract added.)

The addition of rag extract or any of the chemicals did not impart any objectionable or foreign taste to the product.

Note : Rag extract was prepared by boiling the rag of the fruit with an equal amount of water, for an hour (making up the loss of water during boiling) and straining through muslin cloth.

Other citrus squashes. Similar experiments were later extended to other citrus squashes, in order to make the pulp distribute uniformly in the bottled product. Seventy-six sets, collectively of orange, grape-fruit, lemon and *sangtra* squashes were prepared. In some of the sets, the rag of the fruit was replaced by an extract of *galgal* rag. Results of practically similar nature were obtained in case of all squashes, except that the rag extracts of grape-fruit and *sangtra* imparted bitterness to the products.

Experiments carried out in two factories, however, revealed that the seasonal factor was greatly responsible for the usefulness of the method of addition of rag extract ; since the extracts of orange and *galgal* fruits prepared in the beginning of the season were bitter in taste while they were not so when prepared in the laboratory towards the end of the season.

Artificial colour for orange squash

In order to select a suitable artificial food colour for use in orange squash, four different orange food colours were tested separately as well as in combination with two yellow food colours. Sets of orange squash prepared with the addition of these

colours were stored (i) in the laboratory, and (ii) in an underground basement and were examined during storage for general appearance and fading of colour. Colour determinations were also made with a Lovibond's Tintometer. Out of the various colours, Edicol orange A.G. (I.C.I.) added @ 3 gm. per 100 lb. squash, in combination with an equal amount of tartrazine yellow, gave comparatively the best results showing minimum fading. Orange C.S.I. powder colour (S. and H. London) added at 2 gm. per 100 lb. squash and Edicol sunset yellow F.C.S. (I.C.I.) added @ 3 gm. per 100 lb. squash; in combination with equal amounts of tartrazine yellow, also yielded good results. No appreciable difference of fading was, in general, observed under the two storage conditions.

Squashes without chemical preservatives

A simple method for making citrus squashes in the homes (without using the usual preservatives) was worked out for lime, lemon, grape-fruit, malta and *sangtra* squashes. It consisted in filling the bottles with pure crystalline cane sugar and then adding as much juice gradually as could be absorbed by the sugar. The bottles after corking were kept in the sun and shaken off and on to dissolve the sugar. (To juices of malta, grape-fruit and *sangtra*, etc., which are deficient in acid, citric acid at the rate of 5 to 6·5 per cent had to be added to get a desirable taste.)

The products obtained by the above method had excellent keeping qualities.

Preparation of fruit juice concentrates

Experiments on concentration of fruit juices were undertaken only by the freezing method with a view to standardise the method and equipment for the purpose and to explore the possibilities of concentrating the various fruit juices. It may be pointed out that these concentrates are very important as aerated waters offer an enormous scope for the use of real fruit juice concentrates in place of synthetic essences mainly in use at present. Various freezing equipments such as the cold storage chamber, an ice cream freezer, a home-frigidaire and the brine tank of a commercial ice factory were used. Out of these, home frigidaire proved to be of some use for small scale work (concentration of bigger lots was greatly delayed and this entailed heavy losses of vitamins) but freezing in a commercial ice factory was found to be the only method best suited for concentration on a moderate or large scale. Most of the experiments on concentration of juices of lime, lemon, orange, mango, *phalsa*, etc., were, therefore, carried out only in an ice factory.

Great difficulty was experienced in selecting suitable containers for freezing of juices in the ice factory. Ordinary galvanized iron ice cans were found unsatisfactory, as they were corroded by the juice. Efforts to get them electroplated by copper or silver were not successful. With a coating of wax on their inside, these cans proved useful for the purpose. However, second hand motor rubber tubes proved to be most satisfactory and did not impart any objectionable taste or flavour to the product. In the method developed for the concentration of juices, the juice was put in motor rubber tubes, which were clamped with suitable water-tight clamps and suspended in the brine tank of an ice factory. Water in the form of ice crystals was removed from the frozen mass by centrifuging it in a basket centrifuge.

Juices of malta, *sangtra*, lemon, lime, mango, apple, *phalsa*, *jaman* and pomegranate, were successfully concentrated by repeated freezing and centrifuging as above to about 50° Brix concentration. The concentrates of first six kinds of fruits mentioned above, could in general be best preserved with SO_2 or sugar, while those of the last three named fruits with sodium benzoate or pasteurization. All these possessed good taste and flavour and gave pleasant drinks when diluted appropriately with plain soda water and a proper sugar acid balance made up with added sugar or acid or both. The above results have indicated that an ice factory can be used with advantage, for the preparation of fruit juice concentrates for the benefit of aerated water industry.

Fermented and unfermented beverages from water melon juice

The ripe water melons have usually a pulp of deep pink colour (removable from the rinds by scraping with knives) which yields a palatable juice. The juice could be extracted by pressing the pulp in a basket press. The yield was 35 to 45 per cent juice containing 6 to 7 per cent soluble solids. Experiments conducted to investigate the possibilities of utilizing this juice for the preparation of some suitable beverages are briefly described below :

Unfermented beverages. In experiments to evolve a recipe for the preparation of an unfermented beverage of satisfactory quality, pure as well as sweetened juice was preserved as such and with the addition of acid, employing different methods of preservation. As a result of these experiments the following recipe was evolved for the preparation and preservation of melon juice, in the form of a squash of 45° Brix sugar concentration and 1·0 per cent acidity, preserved with 0·1 per cent sodium benzoate, and is recommended for home as well as commercial production :

Juice	30 lb.
Sugar	21 lb.
Citric acid	8 oz.
Sodium Benzoate	23·5 gm.

Fermented beverages. In attempts to prepare wines from melon juice, samples of wine with 7·0 to 12·0 per cent alcohol content could be prepared but the flavour of these was not agreeable.

Loss of sulphur dioxide in juices

Due to lack of information on the effect of temperature on the loss of sulphur dioxide and its method of adding to juice, one of the biggest squash manufacturers in the North, during one season, suffered very heavy financial losses on account of the spoilage of juice in barrels. To study this problem, determinations of SO_2 added to lime juice kept under different conditions, at constant temperatures varying from 50°F. to 110°F. were made in the laboratory. The results obtained which are presented in Table III revealed that the loss increased quite rapidly with the increase in temperature at which SO_2 was added. From these results which are of great practical importance, useful curves were obtained to find out the loss of SO_2 at any working tmperature which could be used by the manufacturers of squashes with advantage.

TABLE III

Loss of SO_2 in juices at different temperatures (SO_2 at 35 p.p.m. added as potassium meta-bisulphite)

Temperature in degrees	Amount of SO_2 found (estimated) in the juice (p.p.m.)		Loss of SO_2 in the juice (p.p.m.)		Percentage loss of SO_2 in the juice	
	Immediately after addition	Three hours after addition	Immediately after addition	Three hours after addition	Immediately after addition	Three hours after addition
50F.	342	305	8	45	2·3	12·9
60F.	318	309	32	41	9·1	11·7
70F.	306	296	44	54	12·6	15·4
80F.	300	284	50	66	14·3	18·9
90F.	294	269	56	81	16·0	23·1
100F.	285	254	65	96	18·6	27·4
110F.	273	188	77	162	22·0	46·3

For finding out the applicability of these results as to the loss of SO_2 under commercial conditions of packing, storage, etc., of juices and squashes, experiments were undertaken on the spot, in two factories. At one place, 11 to 16 per cent loss of SO_2 took place during the mixing of the preservative. A further loss of 12 to 17 per cent occurred during the process of bottling, which was done in a vacuum filler, under a vacuum of 20 to 23 in. of mercury.

At the other factory the loss of SO_2 during the process of filling juice in barrels was found to be dependent on temperature as well as the method of addition of the preservative. The loss, in general, was more when the preservative was added into the barrels before filling them with juice, than when it was added after filling the barrels with juice, and just before plugging them. During storage, the loss of SO_2 was found to range from about 5·0 per cent to about 20 per cent in 7 barrels during about 3½ months of winter season ; with the approach of summer, during a later storage of about 3 months, a further loss of SO_2 ranging from about 20 per cent to about 28·0 per cent was found to take place in the above barrels. The results obtained showed that the construction and nature of wood of the barrels, method of handling, temperature of filling, etc. were controlling factors for these losses during storage. Application of shellac and white lead coatings on the outside of barrels, did not help in reducing these losses.

On the basis of these experiments, it was concluded that for proper storage of juice in barrels, after every 2 to 3 months during the storage period, it should necessarily be topped up with the preservative, i.e., an additional amount of preservative to make up for the loss, should be added to the juice in barrels.

V. *Pickles and condiments*

Vinegar pickles

Development samples of vinegar pickles received for tests in the laboratory, were rather mashy and cloudy in appearance. Experiments on pickling of

vegetables like cauliflower, onions, pepper, cucumber, etc., were therefore, started to investigate the causes of these defects and to standardize a method for preparing pickles of standard quality, free from the above defects. Results of these experiments indicated that improper salting of the vegetables prior to pickling was the main cause of mashiness and cloudiness in pickles. Standard methods of 'salting and finishing, etc.,' followed in the laboratory for the pickling of various vegetables and olives, are given below :

Vegetables. Vegetables are salted at 40° Salometer (10 per cent brine) for six weeks, to complete their fermentation. Loss in concentration of brine should be made up every day by addition of salt and vegetables kept immersed in it. After this the concentration of brine is raised by 2° Salometer every 3 days till it reaches 60° in onions, chillies and green tomatoes and 80° Salometer in case of cauliflower. After maintaining the vegetables at the maximum concentration of brine for two weeks, it is washed thoroughly to remove excess of salt. It is then kept immersed in priming vinegar of about 5 per cent acidity for a week after which it is removed and finally bottled with sour (white distilled) or sweet vinegar of 4 to 4·5 per cent acidity.

Olives. Salting of olives is started with 30° Salometer brine and salinity increased by 2° on alternate days upto 40°. After a month's fermentation, they should be washed and given a four hours' dip in 1·5 per cent lye (sodium hydroxide solution) ; again washed thoroughly for a week in water, brined in 10, 20 and 30° Salometer brines with two days' intervals and finally bottled in fresh brine of 30° Salometer.

Standardization of ingredients used in curry powders

With a view to fix standards for good samples of curry powder both with regard to quality and fineness, at the instance of the Supply Department, experiments were undertaken in which complete physico-chemical analysis of seven different standard samples of curry powders was carried out. The standard method used in determination of granularity of cereal flours with slight modifications, was adopted (as given under) for the granularity test in curry powders to fix suitable standards for the limitations of the proportions of different types of particles, viz. very coarse, coarse, fine and very fine, etc. in a good sample. Chemical analysis involved the determinations of certain important chemical constants such as volatile substances alcoholic and water extracts, crude fibre, ash, proteins, etc.

Granularity test. A known weight of the sample is suspended in acetone-petroleum ether mixture, in a 50 c.c. burette and the sedimentation of the particles observed. From observations made of the layering of such sedimenting particles, certain standards for the limitations of the volumes occupied by different types of particles, were fixed as under :

(i) Coarse and very coarse particles not less than 5·0 c.c. and not more than 7·0 c.c. when 5 gm., sample is used for the test.

(ii) Fine and very fine particles not less than 3·0 c.c. and not more than 4·0 c.c. when 5 gm. sample is used for the test.

(iii) The total volume occupied by any one sample of 5 gm. should not exceed 10 c.c. by volume when suspended in the acetone-petroleum ether mixture.

VI. *Miscellaneous products*

Synthetic lime juice cordial powder. As a result of experiments carried out in this connection on behalf of the Supply Department, two suitable recipes were evolved and are given below:

	Sugar	Citric acid	Lime clour	Essence
Low acidity	1 lb.	1¼ oz.	1 c.c. (0·5 per cent solution)	0·5 c.c. (Nu-lime extract)
High acidity	do.	3 oz.	do.	do.

Experiments on the method of roasting, chemical composition and cost of production of roasted groundnuts

In these experiments, a method of roasting groundnuts and the temperature of roasting, were standardized at the instance of the Supply Department. This consisted in keeping sand in the roasting pan at the rate of one half the weight of the groundnuts and regulating its temperature at 200 to 230°C. by heating it uniformly. The cost of roasting and chemical composition regarding moisture and oil content before and after roasting were experimentally determined.

Glossary

Serial number	Local names in the Punjab	Possible English equivalents	Specific names
1	*Galgal*	Elephant lemon	*Citrus limonia*, Osbeck
2	*Malta*	Orange	*Citrus sinensis*, Osbeck
3	*Sangtra*	Mandarin	*Citrus noblis*, Lour
4	*Falsa or phalsa*	...	*Grewia asiatica*
5	*Jaman or jamu*	*nil*	*Eugenia jambolana*

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REFERENCES

Girdhari Lal and Sadasivan, T. S. (1942). Pickling of vegetables. *Punjab Fruit Journal*, VI, 21

——— (1944). Standardization of curry powders. *Indian J. agric. Sci.*, **XIV**, 4

Girdhari Lal and Jain, N. L. (1944). Dehydration of vegetables. *Punjab Fruit Journal*, **VIII**, 29

Girdhari Lal and Nagina Lal Jain, (1945). Research note on the quick sedimentation of lime juice for the manufacture of lime juice cordial. *Indian J. agric. Sci.*, **XV**, 1

——— (1945). Research note on distribution of fruit pulp in citrus Squashes. *Indian J. agric. Sci.*, **XV**, **5**

——— (1947). Canning trials on fruits: *Indian J. agric. Sci.*, **XVII**, 3

——— (1948). Preservation of water melon juice. *Indian Fmg.*, **IX**, 2

——— (1951). Canning of oranges. *Indian J. Horticulture*, **VIII**, 2

——— (1950). Prevention of mould growth in jams and jellics, packed in jars lacking airtight seal. *Indian Food Packer*, **IV**, 6

Department of Agriculture, Punjab (1944). 'Reprocessing of poor quality dried fruits' as leaflet No. 188

——— (1944). 'Vinegar pickling of vegetables' as leaflet No. 190

——— (1944). 'The Tunnel dehydrator and dehydration of vegetables', Leaflet No. 189

Lal Singh. Girdhari Lal and Jain, N. L. (1944). Reprocessing of dried fruits. *Indian Fmg.*, **V**, 9

DESCRIPTIONS OF NEW AND RECORDS OF KNOWN CHALCIDOIDEA (*PARASITIC HYMENOPTERA*) FROM INDIA*

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(With sixty-three text-figures)

In the course of the taxonomic revision of the Indian Chalcidoidea (financed by the Indian Council of Agricultural Research), I came across several new species parasitic on different insect pests. I have described here ten of these and have recorded six known species. The types of the new species are in the School of Entomology for the time being.

The material was received from the Head of the Division of Entomology, Indian Agricultural Research Institute, New Delhi; Entomology Section, Government Hill Fruit Research Station, Chaubattia (U. P.); Professor of Agricultural Zoology, Agricultural College, Kanpur; Entomologist to the Government of the United Provinces, Kanpur; R. S. C. R. Station, Pallam (Travancore) and Dr K. K. Nayar, University College of Science, Trivandrum. I take this opportunity of thanking Dr M. S. Mani, Professor of Zoology and Entomology, St. John's College, Agra, for guidance and confirmation of identifications.

Family TORYMIDAE

Torymus chaubattiensis, sp. nov.

♀ Length 2 mm., metallic green. Reticulately sculptured, sparsely clothed with silvery-white pubescence. Head viewed from above: vertex closely rugosely punctate, in between the ocelli the punctures shallow; ocelli arranged in a triangle, the ocelli more close to the eye than to each other; ocellocular space equal to the ocellar diameter; interorbital space three-fifths the width of the head; front ocellar space less than half the interocellar; occiput concave, dull and obscurely longitudinally striate. Viewed in front broadly rounded; width one and one-fifth the height; face convex; frons with the scrobes deep below, parallel and close together with a median carina in between; eyes finely pubescent; inner orbital border straight, slightly converging above; gena one-fourth the innerorbital length; clypeus straight, not dentate below; mandibles tridentate, first tooth acute, second obtuse, third truncated. Viewed from side postorbital space nearly one-third the width of the head, sparsely setose, shallowly and closely punctate; metallic green. Antennae dark brown; clothed with fine short pubescence; inserted well above the level

*Contribution No. 4 from School of Entomology, St. John's College, Agra, published with the permission of Professor of Zoology and Entomology.

of the lower orbital border ; the space between the antennal socket is slightly less than that between the socket and the orbit ; segments thirtheen ; scape, pedicel, one ring-joint, funicle seven, club three ; scape slender, pale brown and slightly curved, not reaching the front ocellus ; pedicel dark brown, one and a half times as long as thick, less than one-third the scape ; ring-joint narrower than the pedicel, half as long as wide (Fig. 3) ; first funicular segment two-thirds the pedicel, length equal to the diameter, second funicular segment slightly thicker but nearly as long ; succeeding segments equal to the first in length but gradually growing wider ; seventh funicular segment one and a half times as wide as long ; club distinctly thicker than funicle and nearly half as long, apically blunt (Fig. 1). Thorax rugulose, matt with a few scattered shallow punctures especially anteriorly on the scutum and on the scapula ; parapsidal furrows complete, deep ; scutellum when seen infront slightly projecting behind, sculptured like the mesonotum, convex ; tegulae dark brown ; mesopleurae smooth behind the pleural suture but rugulosely sculptured infront ; propodeum smooth, shiny with no trace of carinae, spiracle small, circular. Legs with coxae and hind femur metallic green ; fore femur in the basal half externally, whole of the hind femur metallic green ; fore femur apically, hind femur at extreme apex, all tibiae and tarsi brown ; hind coxae and femur sculptured like the thorax ; hind tibiae with one short apical spur which is one-fifth the metatarsus ; metatarsus half the length of the hind tarsi and one-third the tibiae. Wing hyaline (Figs. 2 and 4), more than twice as long as broad ; veins light brown ; submarginal twice the marginal ; postmarginal one-third the marginal and about twice the stigmal ; stigmal short not exceedingly narrow behind base ; stigma moderately large ; discal pubescence short and sparse ; marginal fringe short ; submarginal with a row of eight long equally spaced setae in the straight part, two setae on the distal curved part ; marginal and postmarginal veins with a double row of short, stout and stiff setae. Abdomen as long as the thorax, the segments smooth and shiny ; basally strongly convex, slightly compressed at the sides especially below ; ovipositor sheath well exserted, a little shorter than the abodmen.

Holotype. 1♀ in spirit, wing and head on slide, reared from *Aphis helichrysi* Kalt. Chaubattia (U.P.), 12-V-1947. *Z.* A. Siddiqi. Registered No. 28.

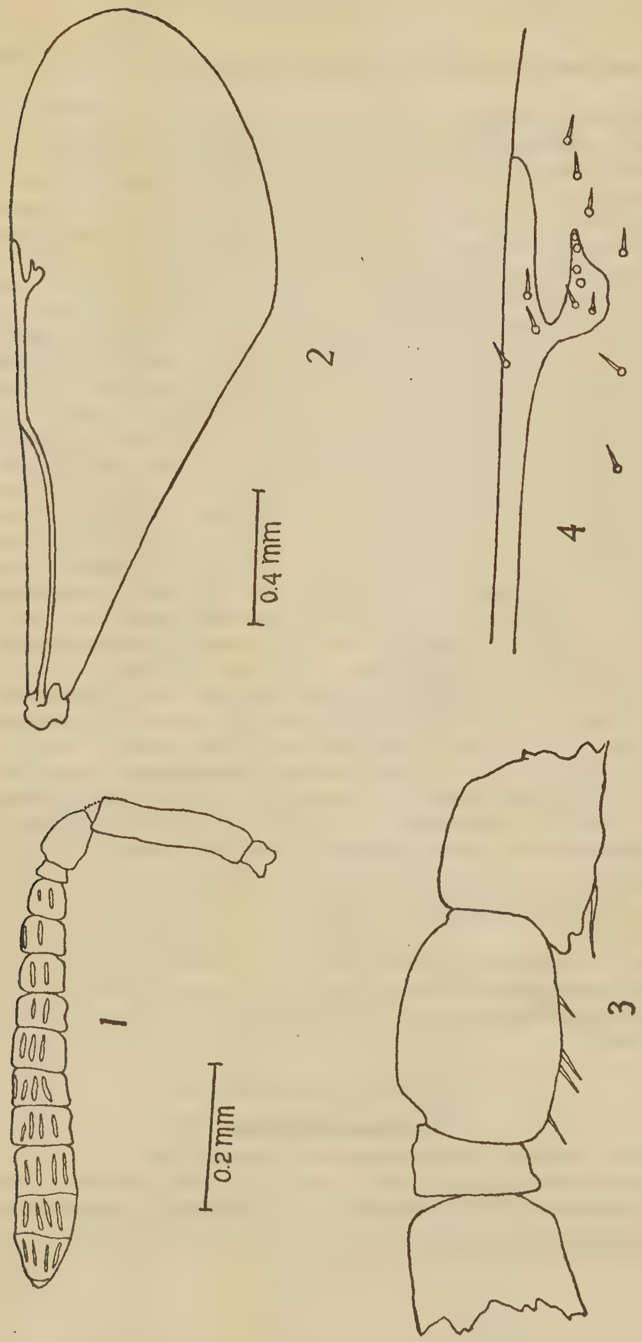
This is the first record of a species of *Torymus* (Dalman) Thompson from India. The only other species known from the Oriental Region is *ceylonicus* described by Motschulsky[1] from Ceylon but has not been so far recognized.

Family EURYTOMIDAE

Prodecatoma mangicola, sp. nov.

♂ Length 1·4 mm. black. Head viewed from above ; vertex narrow, extremely shallowly and closely punctate, interorbital space approximately three-fourths the width of the head ; ocelli almost in a slightly curved line ; lateral ocelli very close to the eyes ; ocellocular space equal to the ocellar diameter ; ocelli very widely separated from each other (Fig. 8) ; occiput very deeply concave in the middle, laterally flat, dull and finely rugosely striate. Head viewed infront, clothed with

[1] **Motschutsky (1863),** *Bull. Soc. Imp. Nat. Moscon,* **36** (3), 47



FIGS. 1-4. *Torymus chaubattiensis*, sp. nov. ♀
1. antenna, 2. wing, 3. pedicel and ring-joint, 4. stigmal and post marginal veins

moderately dense, long pubescence ; oval ; frons excavate, shallowly excavate in the middle, minutely and closely punctate ; front ocellus just within the frontal impression ; inner orbital border straight ; face slightly convex, dull, finely and closely rugosely punctate ; gena three-fourths the inner orbital length ; mandibles tridentate, first tooth large, the teeth blunt ; antennae light testaceous brown, inserted close together near the middle of the face ; segments nine ; scape, pedicel, funicle four, club three ; scape slender, long and reaching beyond the front ocellus, slightly swollen before the middle below, five times as long as broad ; pedicel nearly half the first funicular segment, twice as long as broad ; funicle deep incised above and with long stems and with two whorls of long setae above, segments subequal except the last which is slightly shorter ; the first funicular segment slightly more than three-fourths the scape ; club triarticulate, slightly less than the two preceding funicular segments, distinctly longer than the scape (Fig. 6). Thorax not wider than the head ; pronotum closely, rugulosely punctate, dull, large, quadrate, wider than the mesonotum in the middle ; mesonotum more coarsely punctate than the pronotum, dull ; parapsidal furrows deep and complete ; tegulae light reddish-brown ; mesopleurae with a broad deep femoral impression, finely transversely striate ; scutellum convex, more coarsely rugose ; propodeum deeply declivious and with a faint median carina ; lateral carinae near the margin complete ; spiracles small, circular. Legs except the black coxae and brown hind femur, light testaceous brown ; hindcoxae extremely finely and shallowly punctate ; hindtibiae with two apical spurs, the longer three-fourths and the shorter less than half the metatarsus (Fig. 7). Wings hyaline (Figs. 5, 9 and 10) ; fore wing twice as long as broad, with discal ciliation not dense ; marginal fringe moderately long ; veins light brown ; marginal less than half (12 : 28) the submarginal, twice the stigmal ; postmarginal two-thirds the stigmal, not projecting beyond the level of the stigmal ; stigmal very slender beyond base ; submarginal distinctly broken distad with a few discal cilia. Abdomen small, globose, slightly laterally compressed with a long petiole ; petiole twice the hindcoxa and slightly longer than the abdomen ; the first tergite twice the second and equal to the third ; abdominal tergites smooth and polished.

Holotype. 1♂ in spirit, wing and head on 1 slide, larval parasite of Cecid fly from spherical galls of mango, Kanpur (U.P.), 1-IV-1947. R. L. Gupta, Registered No. 22.

This is the first definite record of a species of the genus from India. Pruthi and Mani[1] recorded an unidentified species of the genus as parasitizing the larvae of the weevil *Microlarinus rhinocylloides* Hochh. which bore into the fruits of *Tribulus* s.p. in Delhi.

Family PTEROMALIDAE

Pachyneuron ferrierei Mani

Mani (1939). *Pachyneuron ferrierei, Indian J. Ent.*, 1 (1 and 2), 83

I refer to this species 1 ♂ with register number 30, parasitic on *Aphis helichryis* Kalt. Chaubattia (U.P.), 18-IV-1947. Z. A. Siddiqi. The species was originally

[1]Pruthi and Mani (1938). *ICAR Misc. Bull.*, No. 30, 7

FIGS. 5-10. *Prodecatoma mangicola*, sp. nov. ♂
5. wing, more highly magnified, 6. antenna, 7. hindleg, 8. head infront, 9. stigmal vein, 10. wing

described from the same locality as parasitic on an aphid causing leaf-curls of peach. It is easily distinguished from the other species of *Pachyneuron* by its mandible being tridentate on the left and tetradentate on the right side and by the postmarginal vein being twice the stigmal.

Aplastomorpha calandrae (Howard)

Howard (1883). *Pteromalus calandrae, Rep. Ent. U. S. Dept. Agric.* Washington, 273
Gahan (1923). *Aplastomorpha calandrae, Proc. ent. Soc.* Washington, **25**, 188
Mani (1938). *Aplastomorpha calandrae, Cat. India Ins.*, **23**, 103
Pruthi and Mani (1939). *Aplastomorpha calandrae, ICAR Misc. Bull.*, (30) 18

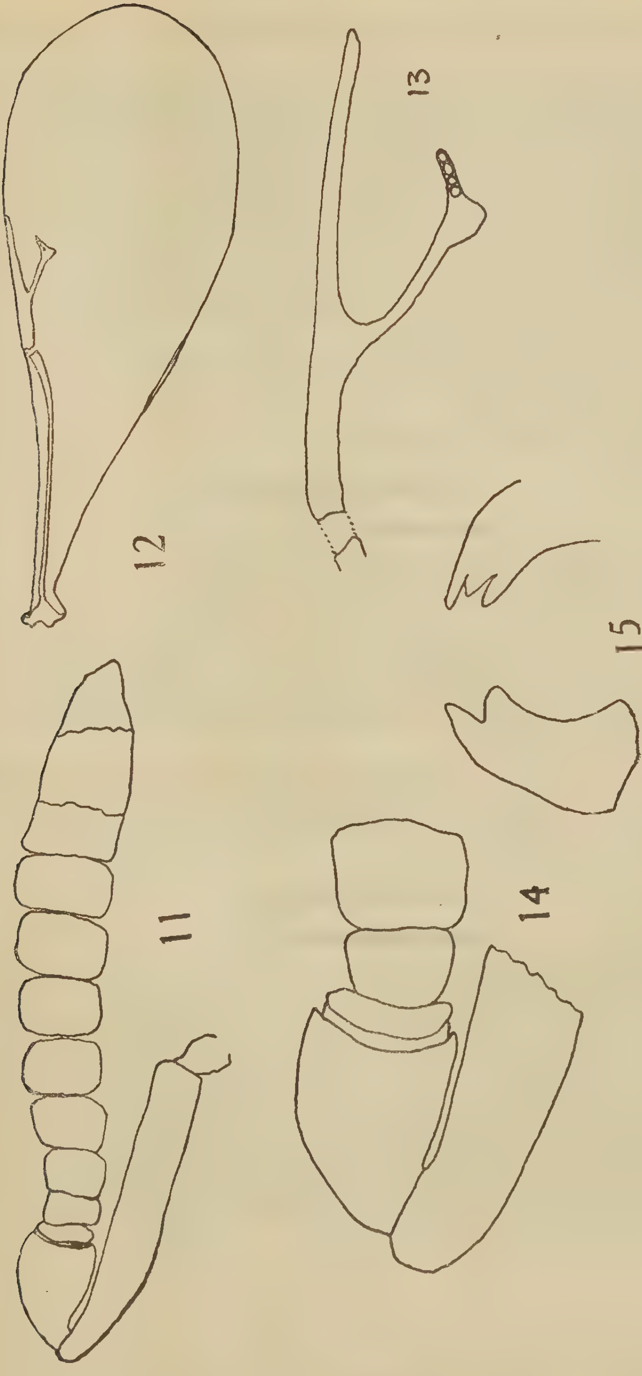
I refer to this species 4 ♀♀ with register numbers 47, 48 and 50, received from the Division of Entomology, Indian Agricultural Research Institute, New Delhi, and bred from a culture of mixed infestation of *R. dominica*, *L. oryzae*, *O. surivamensis* and *T. castaneum* in wheat, *jowar* and maize by S. M. Chatterjee.

The species, common in stores, was originally described by Howard under the genus *Pteromalus* but was transferred to *Aplastomorpha* by Gahan in 1923. Gahan also recorded it from South India. Outside India, the species occurs in Hawaii, where it parasitizes *Calendra oryzae* (Linn.)[1]. It has also been reared from *B. analis*, *B. chinensis*, *B. phaseoli* and *B. quadrimaculatus* (Fab.).

Pachycrepoideus indicus, sp. nov.

♀ Length 1·8 mm. black. Head wider than the prothorax, equal to the distance between the tegulae. Viewed from above rectangular, twice as wide as long ; vertex shallowly and sparsely punctate, setose ; interorbital space half the width of the head, ocellocular space two-thirds the interocellar and equal to the front ocellar space ; occiput dull and very slightly concave. Viewed infront oval ; above the insertion of the antennae face smooth and polished, below closely and shallowly punctuate with long villous setae ; antennae inserted far below the middle of the face ; the distance between the antennal sockets equal to the distance between the socket and the eyes ; eyes circular and naked ; frons excavated ; gena half the inter, orbital length. Viewed from side postorbital space one-fifth the width ; genal space one-third the height ; twice as high as thick. Mandibles left bi- and right tridentate, first tooth large and acute (Fig. 15). Antennae with thirteen segments ; scape pedicel, one ring-joint, funicle seven and club three ; brown ; scape slender, long and just reaching the front ocellus, more than six times as long as broad ; pedicel four times as long as the first funicular segment, twice as long as broad ; the ring-joint only slightly shorter than the first funicular segment ; funicular segments gradually increasing in size, the last thrice as long as the first ; club triarticulate and equal to the three preceding segments of the funicle, about two-thirds the scape (Figs. 11 and 14). Thorax with pronotum towards the lateral sides closely regulosely punctuate, in the middle somewhat smooth and shiny ; large, quadrate mesonotum more closely punctate than the pronotum, dull ; parapsidal furrows deep and complete ; tegulae black ; mesopleurae with a shallow femoral impression, obscurely

[1] Timberlake (1924), *Proc. Hawaiian Ent. Soc.*, **5**(3) : 422.



FIGS. 11-15. *Pachycrepoideus indicus*, sp. nov. ♀
11. antenna, 12. wing, 13. stigmal vein, 14. pedicel and ring-joints, 15. mandibles

shallowly punctate but mostly smooth and shiny ; axillae triangular and not meeting in the middle ; scutellum slightly convex and smooth ; propodeum rugulose, strongly punctate with a median carina. Wings hyaline ; approximately thrice as long as broad with discal ciliation moderately dense towards the apex ; veins light brown ; submarginal vein broken distad with a few discal ciliation ; marginal vein equal to the stigmal and three-fourths the postmarginal (Figs. 12 and 13). Legs except the three coxae which are black, rest of the legs are light yellowish-brown ; hindcoxae largely impunctate, the single hindtibial spur straminous and half the metatarsus. Abdomen equal to the thorax, first and second tergites equal, conspicuously large and smooth rest of the tergites reduced ; ovipositor sheath concealed ; petiole well developed and equal to the propodeum.

Holotype. 1 ♀ on slide number 26 bred from *Aphis helichrysi* Kalt. Chaubattia (U.P.), 15-V-1946. Z. A. Siddiqi.

This is the first record of the genus from India.

Family MISCOGASTERDAE

Bruchobius laticeps Ashmed

Ashmead (1904). *Bruchobius laticeps, Mem. Carnegie Mus.*, **1**(4), 314
Mani (1939). *Bruchobius laticeps, Indian J. Ent.*, **1**,8
Pruthi and Mani (1940). *Bruchobius laticeps, ICAR Misc. Bull.*, **30**, 10

I have before me 1♂, 1♀ labelled, Parasitic on *Bruchus*, sp. on Mung. S. M. Chatterjee collection, New Delhi. 14-I-1948, and 1♀ (mounted on slide number 54) labelled, Chalcids obtained from the culture of *Bruchus chinensis* and *Bruchus analis* in mung (*Phaseolus radiatus*) and cowpea (*Vigna catiang*). S. M. Chatterjee collection, New Delhi.

The species is known to be parasitic in the larvae of *Bruchus quadrimaculatus* Fabr. from America. Mani [*loc. cit.*] bred large numbers of this species in New Delhi as a larval parasite of a mixed infestation of *Phaseolus mungo* by *B. analis* and *B. chinensis*.

Family EUPELMIDAE

Solindenia vermai, sp. nov.

♀ Length 3 mm. dark metallic green. Head viewed from above, vertex clothed with silvery-white pubescence, rugulosely, closely punctate ; ocelli small and arranged in a triangle ; about twice as wide as long ; ocelli nearer to the eyes than to each other, hence ocellocular space less than the interocellar ; front ocellar space slightly less than the interocellar ; occiput concave and longitudinally striated. Viewed infront (Fig. 16) antennae inserted far below the middle of the face, near the mouth border ; face in the middle shagreened ; gena and face below the middle covered with long villous setae and closely, regulosely punctate ; interorbital space less above than below ; genal space half the inner orbital length ; face not deeply excavated but only with scappal furrow, the front ocellus not within this ; antennae inserted close to the mouth border and wide apart from each other. Viewed from side half as wide as

high ; postorbital space closely and shallowly punctate. Antennae dark brown ; segments thirteen ; scape, pedicel, funicle eight and club three ; scape cylindrical, five and a half times as long as broad ; one and a half times as long as the club ; pedicel twice as long as broad, thrice the first funicular segment ; funicle with the first segment shortest, 2, 3, and 4 cylindrical, longer than broad, about thrice as long as broad ; the last segment of the funicle as long as broad and shorter than the second in length ; club three segmented, longer than the two preceding segments of the funicle (Fig. 20). Thorax slightly narrower than the head ; parapsidal furrows incomplete, visible only in basal half ; prothorax narrower, rectangular ; tegulae dark brown ; scutellum evenly shallowly punctate ; mesopleurae dull and without femoral impression, closely and finely punctate. Wings hyaline ; forewing about thrice as long as broad ; marginal fringe moderate ; discal ciliation dense ; an oblique hairless line runs from a little beyond the middle of marginal ; submarginal equal to the marginal ; postmarginal equal to the stigma (Figs. 17 and 19). Legs with the coxae black ; hindtibiae not compressed, dark brown except at apical one-third which is whitish ; hindtarsi brown except the last segment which is black ; hindtibial spur single and one-third the metatarsus ; metatarsus not flat ; fore and hindtibiae slightly darker in basal half ; midmetatarsus armed below with short black denticles ; single midtibial spur as long as the midmetatarsus (Fig. 18). Abdomen as long as the head and the thorax combined ; segments equal and smooth ; ovipositor exserted ; ovipositor sheath black both at extreme base and at apex but white in the middle.

Holotype. 1♀ dissected and mounted on slide, Register No. 8. Adult parasites of the grubs of *Epilachna* sp. Kanpur (U.P.) B. K. Verma.

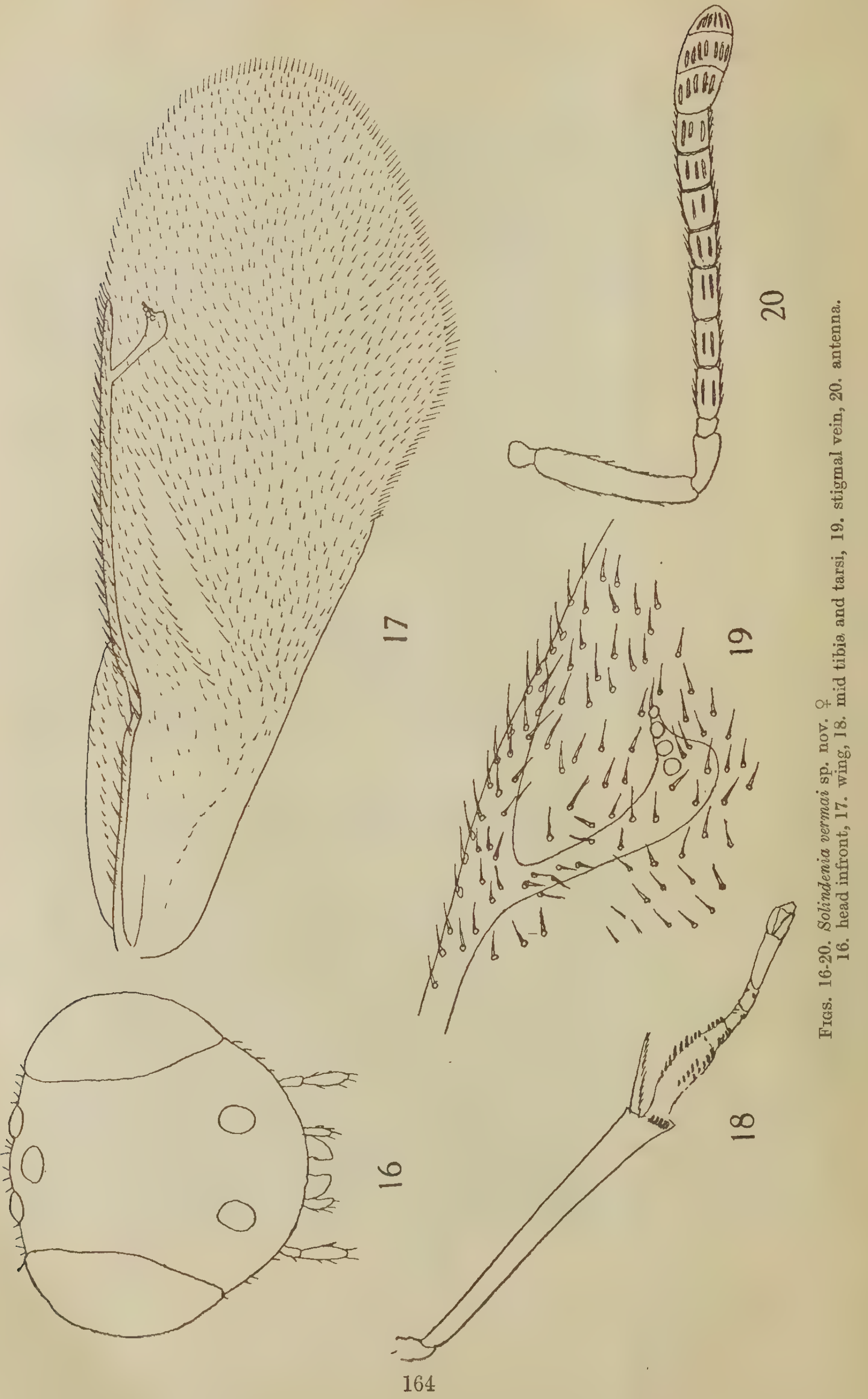
This genus was erected by Cameron[1] in 1883 with *Solindenia picticornis* as the genotype recorded from Australia. This is the first record of a species of this genus from India as well as from the Oriental Region.

Family ENCYRTIDAE

Coccidencyrtus kumaoensis, sp. nov.

♂ Length 0·95 mm. Head black. Viewed from above vertex narrow, ocelli in triangle, the lateral ocelli nearer to the eye margin than to each other ; vertex rugosely punctate, the punctures not very close ; the interocellar space two-thirds the interorbital space ; front ocellar space half the interocellar. Viewed infront oval ; face below and near about the insertion of the antennae punctate as the vertex ; antennal grooves deep and prominent ; antennae inserted in the level of the lower margin of the eye border ; genal space half the innerorbital border ; face on the lower margin sparsely setose ; occiput nearly flat and punctate. Antennae light brown ; segments nine ; scape, pedicel, funicle six and club one ; scape bit dark and not reaching the front ocellus ; cylindrical two and a half times as long as the pedicel or the first funicular segment ; pedicel (Fig. 21) twice as long as broad ; equal to the first funicular segment ; funicular segments of the same size, except for the first which is slightly shorter ; club unsegmented, equal to the last two funicular segments, slightly longer than the scape (Fig. 22). Thorax nearly as broad as the head ;

[1] Cameron (1883). *Trans. Ent. Soc.* London, 189



FIGS. 16-20. *Solindenia vermai* sp. nov. ♀
16. head infront, 17. wing, 18. mid tibia and tarsi, 19. stigmal vein, 20. antenna.

pronotum large, rectangular, closely punctate; mesonotum matt; mesopleurae with the femoral impression faint, closely punctate; disc of scutellum convex, sparsely punctate; tegulae dark brown. Wings hyaline, slightly less than two and a half times as long as broad; marginal vein short, slightly longer than the stigmal; postmarginal almost absent; stigma longer than broad; submarginal long and faint distad with a few long setae along the surface; marginal ciliation dense (Fig. 24). Legs with the apices and base of all the femur, apical half of all the tibiae white; rest of the legs dark brown, tarsi pale. Abdomen as long as the thorax; tergites smooth.

Holotype. 1♂ dissected and mounted on slide No. 27. Parasitic on *Aphi-helichrysi* Kalt. Chaubattia (U.P.) Z. A. Siddiqi. 15-vi-1945.

The genus was somewhat incorrectly described by Ashmead[1] in 1900. Mercet[2] in 1921 and Timberlake[3] in 1927 redescribed it correctly. No species of this genus was recorded from India so far. This is the first record of a species of the genus from India.

Homalotylus flaminius (Dalman)

Dalman (1820). *Encyrtus flaminius, Svensk. Vet. Akad. Handl.*, **41**, 340

Schmied (1909). *Homalotylus flaminius, Gen. Ins.*, fas. **97**, 235

Ramakrishna and Margabandhu (1934). *Homalotylus flaminius, J. Bombay Nat. Hist. Soc.*, **37**, 194

Mani (1938). *Homalotylus flaminius, Cat. Indian Ins.*, **23**, 89

Pruthi and Mani, (1940). *Homalotylus flaminius, ICAR Misc. Bull.*, **30**, 14

Venkatraman (1946). *Homalotylus flaminius, Jl.* Bombay *Nat. Hist. Soc.*, **46**, 3, 527

This species was recorded by Ramakrishna Ayyar and Margabandhu [loc. cit.] on larvae of a unnamed Coccinellid at Coimbatore. Mani [loc. cit.] recorded it on the larvae and pupae of *Adonia variegata*, *Brumus suturalis* and *Chilocorus* sp. from Delhi and on *Novius Guerni* from Coimbatore by Venkatraman. I have before me several ♂♂♀♀ parasitic on larvae of *Rodolia cardinalis* and *Rodalia* sp. predaceous on *Icerya purchasi* at Bangalore, June 1948, V. K. Subramaniam.

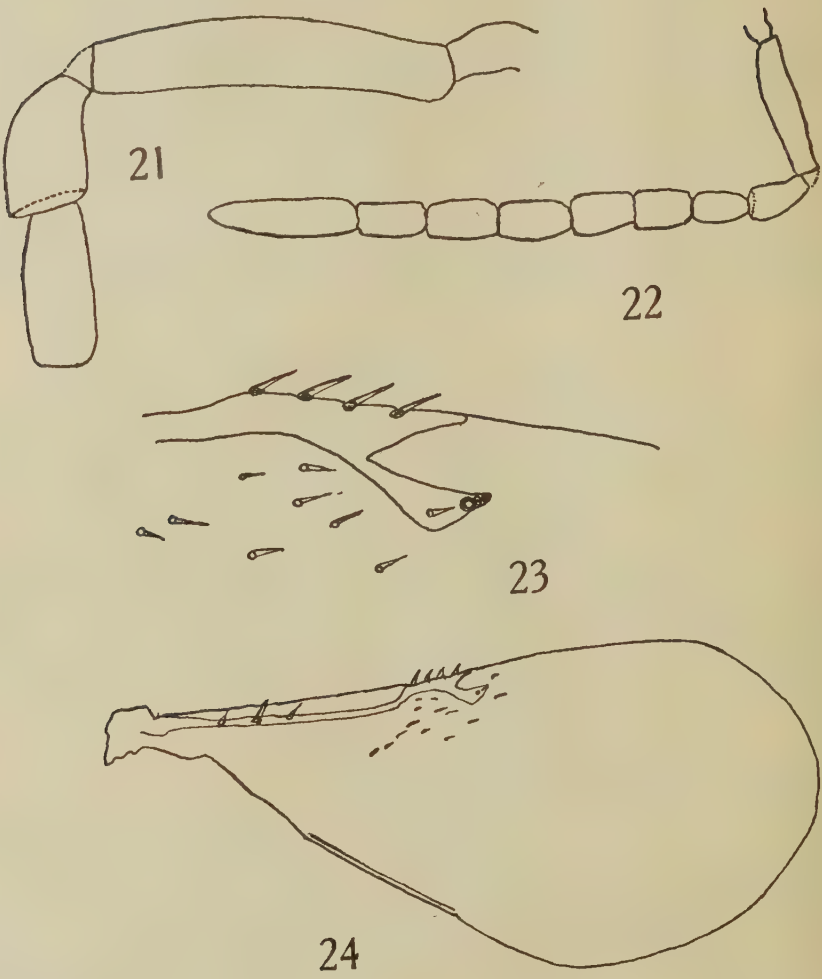
Homalotylus terminalis (Say)

Say, (1878). *Scelio terminalis, Contrib. Maclur. Lye. Philad.*, **2**, 80

Schmied, (1909). *Homalotylis terminalis, Gen. Ins., fas.* **97**, 236

I have before me 1 ♀ in spirit and 1 ♀ on slide labelled, Parasites of the grubs and pupae of *Chilomenes sexmaculata* Feb. B. K. Verma collection. I am informed by Dr. M. S. Mani that L. O. Howard (Chief of Bureau of Entomology, U. S. Department of Agriculture) communicated to Mr. H. M. Lefroy, (letter dated 12-iv-1905, Files of Division of Entomology, Indian Agricultural Research Institute, New Delhi) that specimens reared from larvae of *Chilomenes sexmaculata* Feb. at Surat, were identified by Ashmead as belonging to this species. There is however no previous published record of this species from India. This species is distinguished from the

[1] Ashmead (1900). *Proc. U.S. Nat. Mus.*, **22**: 383
[2] Mercet, (1921). *Fauna Iberica*, Encirtidos, 273
[3] Timberlake (1927). *Proc, Hawaiin ent. Soc.*, 6(3), 517



FIGS. 21-24. *Coccidencyrtus kumaolensis*, sp. nov. ♂
21. scape and pedicel, 22. antenna, 23. stigmal vein, 24. wing.

closely allied cosmopolitan species *Homalotylus flaminius* (Dalman) by the head being slightly wider than long and brownish-yellow ; mesopleurae with brown and with a somewhat metallic bluish lusture.

Encyrtus siddiqii SP. NOV.

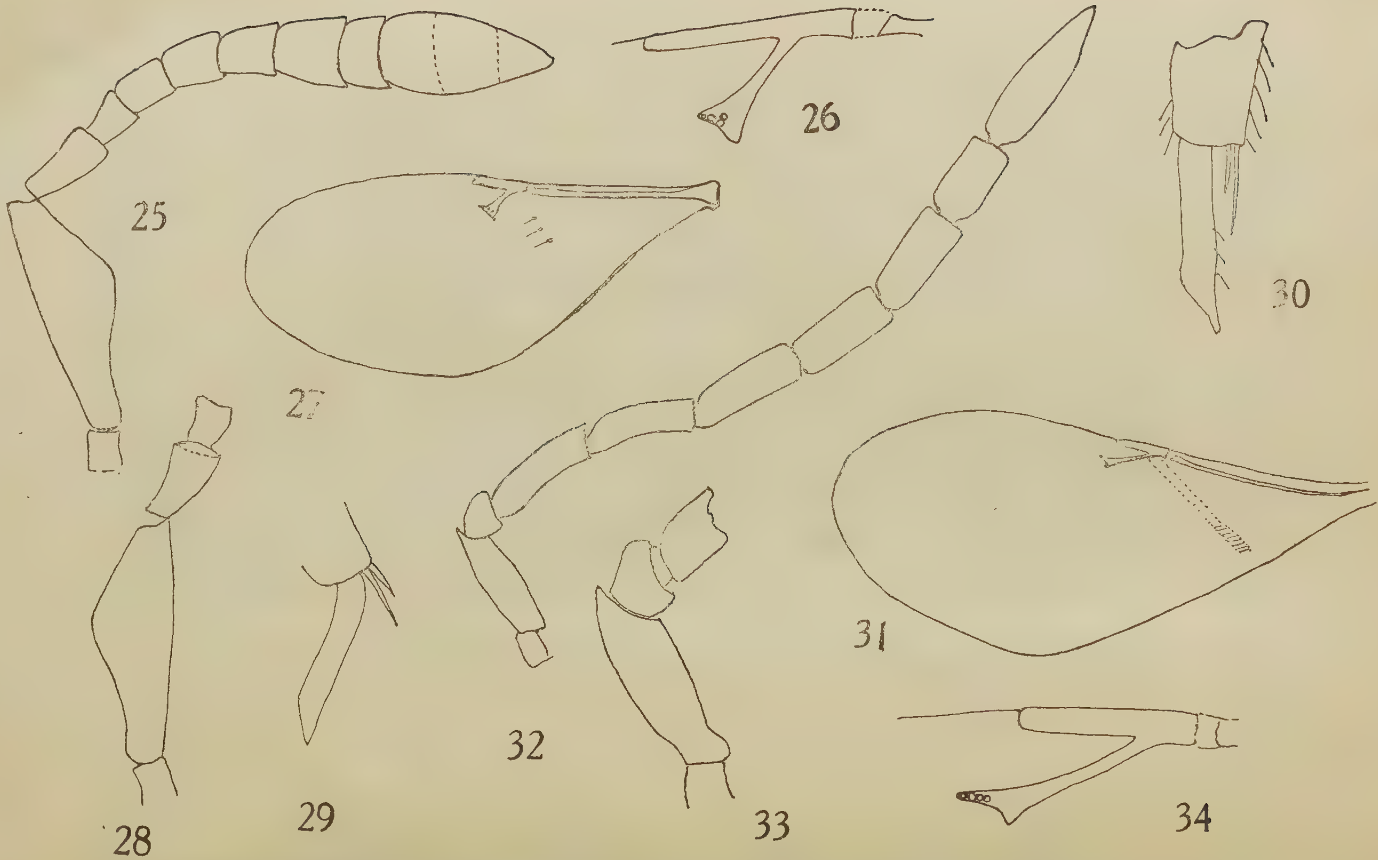
♀ Length 1·2 mm. black. Head as wide as the thorax. Viewed from above vertex closely and strongly punctate ; ocelli in a triangle ; more than twice as broad as long ; interocular space less than half the head width ; ocelli very much close to the eyes than to each other, interocellar space greater than the ocellocular space ; front ocellar space three-fourths the interocellar ; occiput deeply concave. Viewed infront circular ; as strongly and closely punctate as the vertex ; eyes circular ; interorbital space less above than below ; antennae inserted far below the middle of the face ; the distance between the antennal sockets equal to the distance between the eyes and the antennal sockets ; frons deep and extending slightly below the front ocellus ; genal space equal to the innerorbital length. Antennae (figs. 25 & 28) with the scape submetallic, pedicel, except the last segment which is grey rest of the funicle and the club brownish ; segments eleven ; scape, pedicel, funicle six and club three ; scape thrice as long as broad ; swollen in the middle, about thrice as long as the pedicel ; pedicel short half as long as the club, twice the first funicular segment ; funicle six segmented, segments tend to increase in size toward the apex ; fifth or the last but one funicular segment slightly longer than the last ; first funicular segment two-thirds the last and one-fourth the club ; club three segmented, two-thirds the scape. Thorax with pronotum very narrow, closely and shallowly punctate ; mesonotum without parapsidal furrows ; punctate as the pronotum ; tegulae hyaline, towards the apex reddishbrown ; axillae narrow, triangular and not meeting in the middle ; scutellum as long as the mesonotum, closely and shallowly punctate, slightly convex ; mesopleurae matt without femoral impression. Wings (Figs. 26 & 27) hyaline, veins light brown, more than twice as long as broad (9 : 4) ; submarginal distinctly broken distad, slender with a few long discal ciliation ; marginal fringe normal marginal vein very short and about half the stigmal ; stigmal slightly shorter than the postmarginal stigma about four times as long as broad apically ; a hairless line from the base of the stigmal to the lower margin of the wing present. Extreme apex of hind femur, extreme base and extreme apex of tibiae grey, tibiae subbasally black, subapically brown, in the middle pale brown ; midtibial spur single, thick and five-sixths the metatarsus ; hindtibial spurs unequal, shorter one-fourth and the longer half the metatarsus (Fig. 29). Abodomen conic-ovate, shorter than the thorax ; abdominal tergites smooth and dull ; ovipositor concealed.

Holotype. 1♀ parasitic on *Eulecanium coryli* Linn. Chaubattia. (U. P.) 20-v-1945. Z. A. Siddiqi. Register number 46.

Allotype 1♂ dissected and mounted on slide no 46.

The ♂ differs from the ♀ in the following :

Length 1·9 mm. Antennae (Figs. 32 & 33) with only nine segments ; funicle six and club one ; light yellowish-brown with dense ciliation ; scape thrice as long



Figs. 25-34. *Encyrtus siddiquii*, sp. nov. ♀
25. antenna, 26. stigmal and postmarginal veins♀, 27. wing♀, 28. scape, pedicel and the first segment of the funicle, 29. hindtibial spurs, 30. hindtibial spurs, 31. wing♀, 32. antenna♀, 33. scape & pedicel♀, 34. stigma and postmarginal veins.

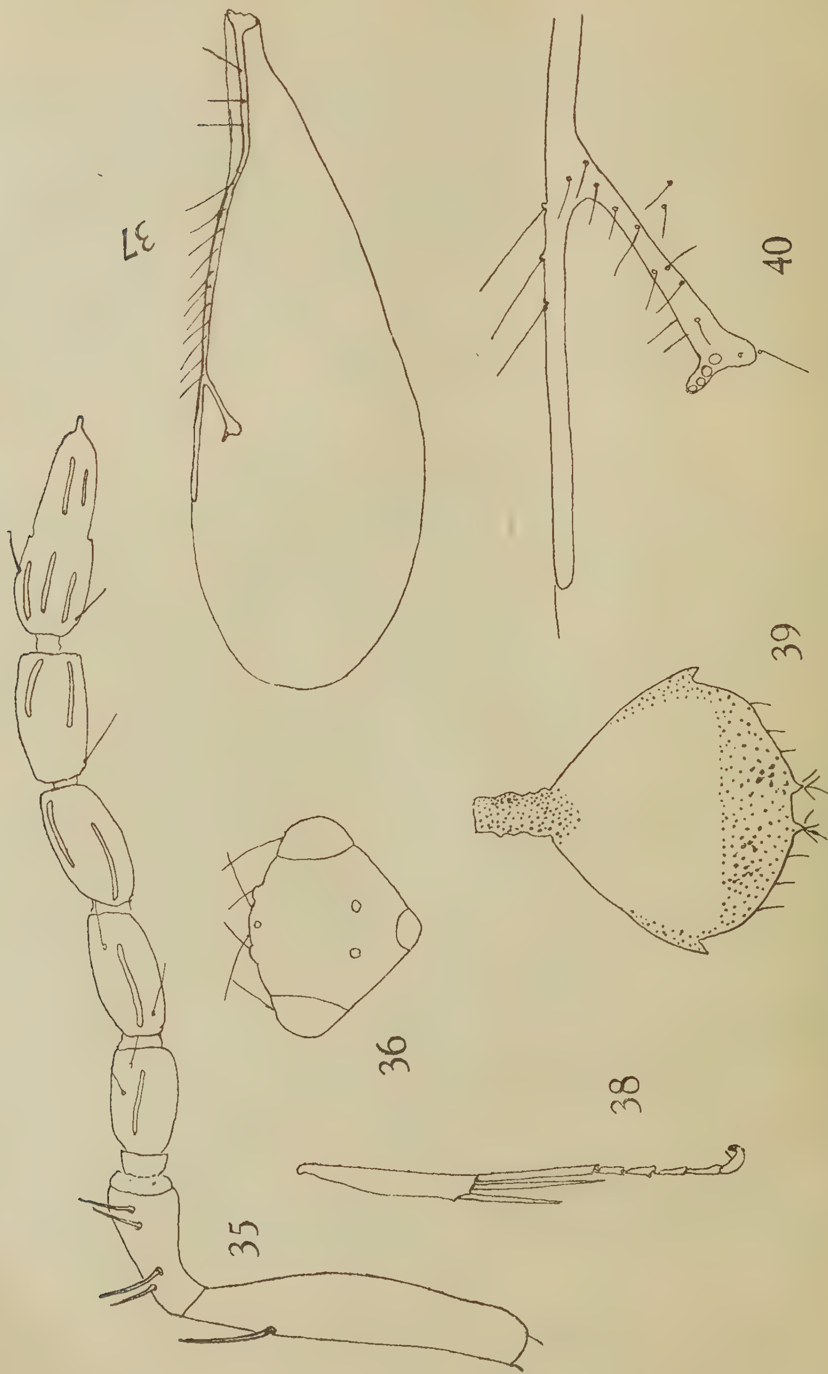
as broad, equal to the first funicular segment ; pedicel short, as long as broad, one-third the scape ; first funicular segment three-fourths the club and one and a half times the last funicular segment ; club entire, twice the last funicular segment. Head viewed infront bluish-green ; circular ; interorbital space less above than below ; antennae inserted below the middle of the face ; face in the middle reticulately shagreened, gena and the lower margin of the face brown, rugulosely, closely strongly punctate ; antennal sockets nearer to the eyes than to each other and joined with a median groove ; innerorbital border straight ; gena one-third the innerorbital length. Wing as shown in (Figs. 31 & 34).

This species has a superficial resemblance to *Encyrtus tessellatus* Dalman[1] but is readily distinguished from it by a single hairless line of the forewing, the differently coloured head, antennae and hindlegs in ♂ and ♀.

Family Elachertidae

Euplectrus spodopterae, sp. nov.

♀ Length 1·8 mm. In most of the specimens head black but below the insertion of the antennae reddish-brown ; in one specimen head entirely black and in a few specimens it is completely reddish-brown. Head wider than the prothorax and slightly less than the distance between the tegulae ; viewed from above thrice as wide as long ; vertex glossy and smooth ; ocelli dark reddish-brown and arranged in a triangle ; interocular space less than three-fourths the width ; ocellcular space equal to the interocellar ; front ocellar space half the interocellar ; bristles as shown in Fig. 36. Viewed infront triangular ; antennae inserted below the middle of the face and on an imaginary line drawn from the lower orbital borders ; genal space slightly more than the innerorbital border (5 : 4) ; face in low power smooth but in high power sparsely punctate with a few bristles. Antennae with the scape light reddish-brown ; pedicel and the ring-joint reddish brown ; first segment of the funicle brown and the rest of the antennae dark brown ; segments eight ; scape, pedicel, one ring-joint, funicle four and entire club. Scape about four times as long as broad, cylindrical and not reaching the front ocellus ; approximately thrice as long as the pedicel ; pedicel longer than the first segment of the funicle with a pair of bristles both at apex and at the base Fig. 35 ; ring-joint fused to the base of the first funicular segment; funicular segments subequal ; club entire and equal to the one and one-half of the preceding segments of the funicle combined ; with a short nipple-like process apically. Thorax black. Pronotum highly declivous infront ; when viewed from above it appears to be very narrow ; finely transversely striate on the lateral margins, in the middle shallowly and reticulately punctate with five long bristles on the posterior margin ; finely pubescent ; mesonotum shallowly and closely punctate ; parapsidal furrows complete ; tegulae reddish-brown ; mesopleurae mostly smooth and shiny with a short but deep femoral impression ; scutellum slightly convex, finely and shallowly punctate ; propodeum smooth with a well marked median longitudinal carina. Wings Figs. (37 & 40) hyaline, slightly less than thrice as long as broad ; submarginal not broken distad with four to five long setae distributed along the margin, equal to the marginal ; marginal with ten long bristles on the margin ;



FIGS. 35-40. *Euplectrus spodopterae*, sp. nov. ♀
35. antenna, 36. head infront, 37. wing, 38. hindtibial spurs, 39. abdomen, 40. postmarginal and stigmal veins.

stigmal slender, shorter than the postmarginal. Legs light reddish-brown except the hindcoxae which has a slight darkening at the base ; the spurs of the hind tibiae unequal, shorter equal to and the longer spur longer than the metatarsus (Fig. 38). Abdomen as long as broad ; reddish-brown in the middle ; petiole, the lateral sides and the apex black (Fig. 39) ; ovipositor concealed.

Holotype 1♀ in spirit parasitic on *Spodoptera mauritia* Boisd. Pallam (Travancore). June '49. J. Johnson. Registered No. 58.

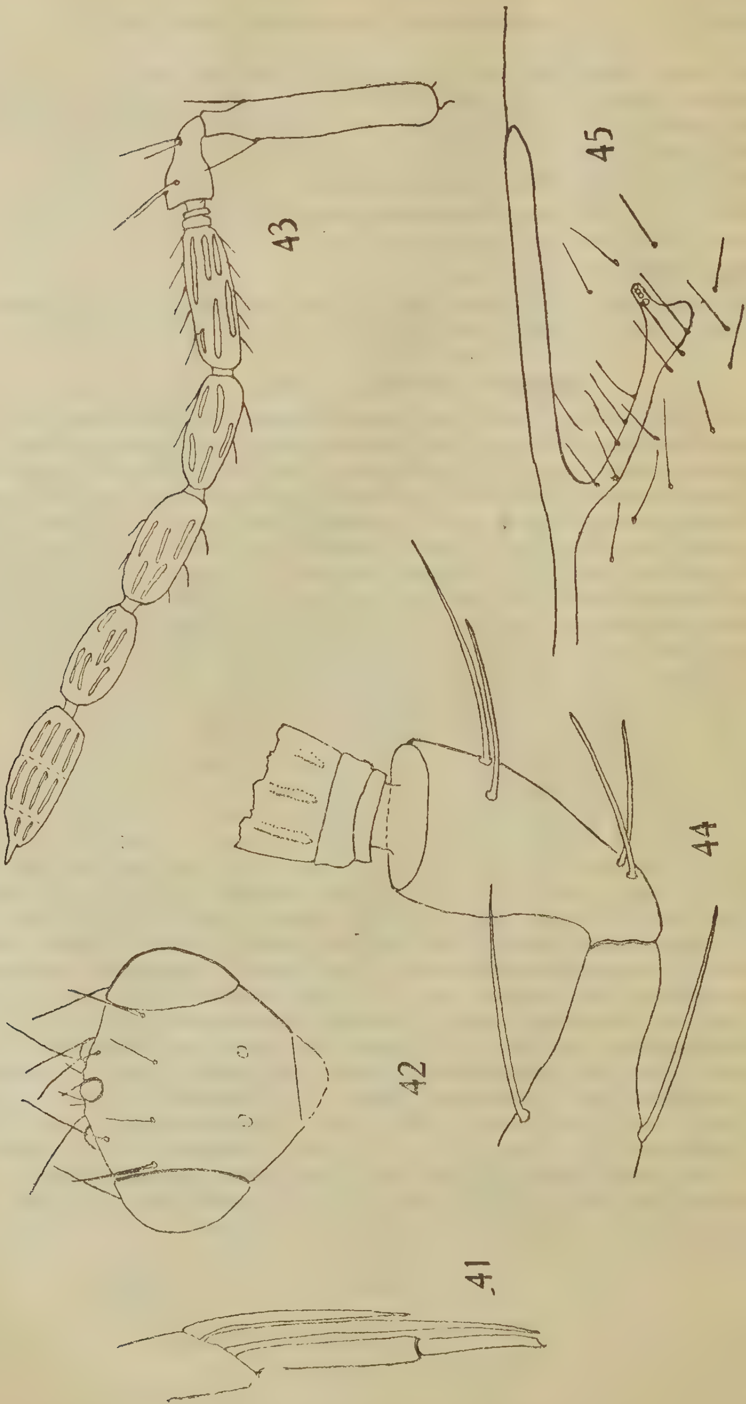
Paratypes Numerous ♀♀ in spirit.

This species due to the pedicel longer than the first segment of the funicle no where fits in the key to Indian species of *Euplectrus* given by Mani.[1]

Euplectrus mathuri, sp. nov.

♀ Length 2·85 mm. Head black, below the antennae light brown. Viewed from above four times as broad as long ; vertex very finely and closely punctate, in low power appears to be matt with fine grains ; margined behind with a transverse row of four fine setae on the margin ; occiput dull and nearly flat ; interocular space slightly more than half the head width ; ocellocular space more than the front ocellar space and half the interocellar. Viewed infront broader than high ; innerorbital border straight ; innerorbital space slightly less below than above ; antennae inserted far below the middle of the face and on an imaginary line joining the lower margin of the innerorbital borders ; antennal sockets nearer to the margin of the eyes than to each other ; face very finely punctate and sparsely setose ; pubescence white ; mouth-parts straminous ; eyes dark-brown ; face in the middle impressed ; genal space shorter than the innerorbital length ; bristles as shown in the figure (Fig. 42). Antennae Fig. 43 except for the scape which is yellowish-white rest of the antennae light brown ; segments nine ; scape ; pedicel, ring-joints two, funicle four and club one ; scape cylindrical, slightly less than six times as long as broad with a pair of bristles towards the apical fourth ; a little less than twice the first segment of the funicle ; pedicel half the first funicular segment with a pair of long, stout bristles both apically and basally Fig. 44 ; ring-joints narrow, the first approximately half the second in length ; except the first funicular segment which is slightly longer than the rest and equal to the club, rest of the segments nearly equal, less than half as broad as long ; the last segment three-fourths the club ; club entire, slightly darker than the rest of the antenna and reduced to a pointed apex, apparently triarticulate Thorax-prothorax matt, narrower than the head, declivous infront with six long slender bristles on the anterior margin ; mesothorax finely rugosely striate with a few scattered deep puncti especially in the region of the scapulae ; with a distinct median longitudinal carina ; parapsidal furrows complete and distinct ; tegulae light reddish-brown ; scutellum finely longitudinally striate, dull ; propodeum except for a prominent median longitudinal carina which is broadened behind mostly smooth and shiny ; mesopleurae dull, smooth and with the femoral impression faintly indicated. Wings 2·5 mm. long ; hyaline ; submarginal entire shorter than the marginal with six long setae distributed along its surface ; stigmal slender and shorter than the

[1]Mani (1935). *Rec. Indian Mus.*, 37(3), 256 (1935)



FIGS. 41-45. *Euplectrus mathuri*, sp. nov. ♀
41. hindtibial spurs, 42. head infront, 43. antenna, 44. pedicel and ring-joints, 45. postmarginal and stigmal.

postmarginal (Fig. 45). Legs including their coxae honey-brown, except for the hindcoxae which is slightly of a deeper tone ; apices of the terminal tarsal segments dark brown ; hind tibial spurs unequal, longer reaching the apex of the second tarsal segment and the shorter equal to the hind metatarsus. Abdomen when seen from above depressed as long as broad, apically black, towards the base with a light brown patch in the middle ; ventrally mostly brown with some darkening towards the margins ; ovipositor concealed.

♂ Length 2·3 mm. resembles ♀ except for the legs being of lighter shade and the abdomen being slightly longer than broad with the ventral side black towards the apex.

Holotype 1♀ in spirit. Register number 129. Parasitic on an Agaristid larva defoliating *Dioscorea belophylla*. R. N. Mathur, New Forest, Dehra Dun (U. P.). 22-VIII-1949.

Allotype 1♂ in spirit.

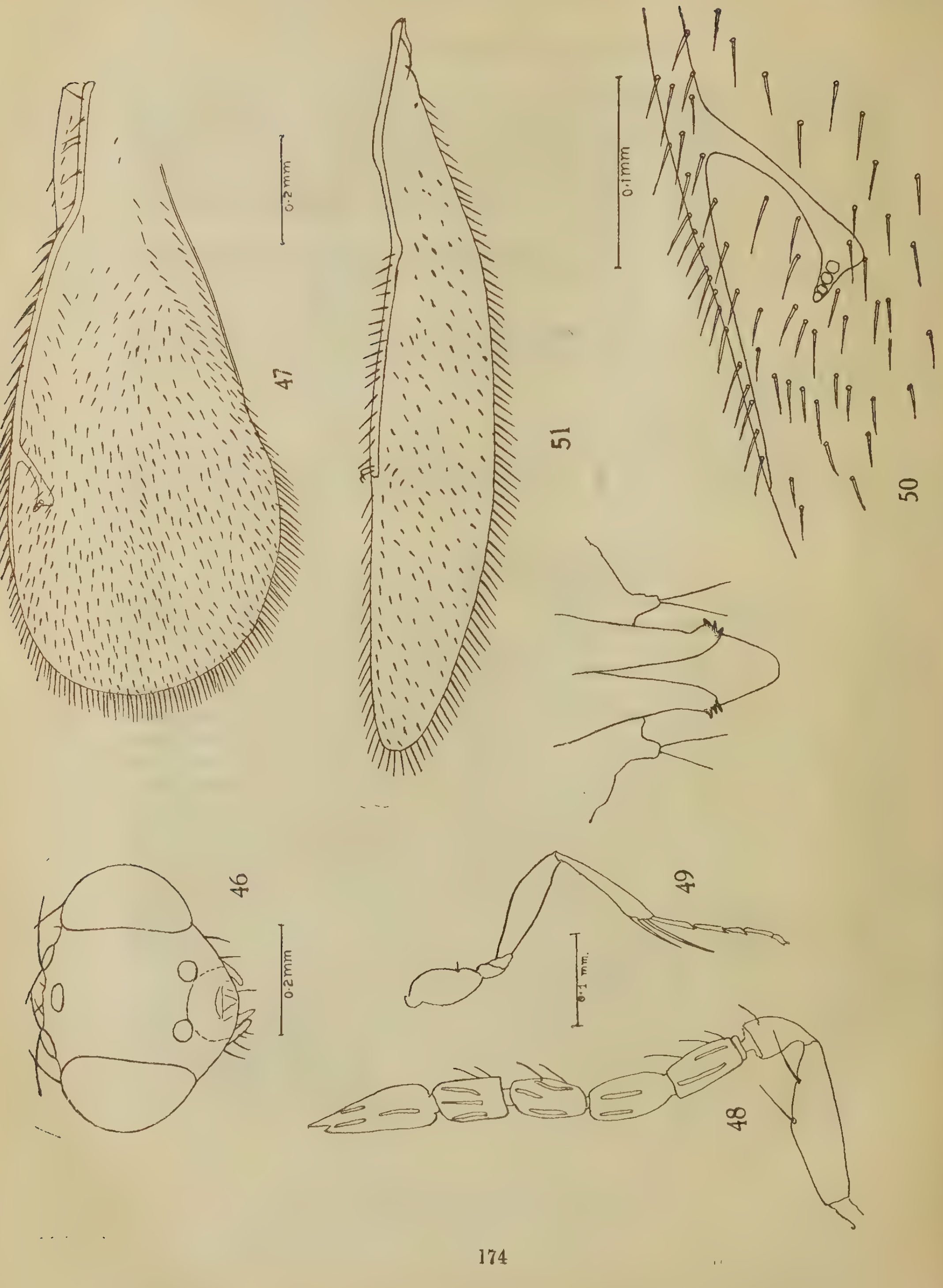
Paratypes 2♀♀ in spirit.

This species runs closest to *E. bussyi* Crawford in Manis key[1] but it is readily distinguishable from it by the subequal segments of the funicle being subequal and the hindioxa brown.

Euplectrus maternus, sp. nov.

♀ Length 2 mm. Head dark brown. Viewed from above two and a half times as broad as long ; interocular space twice the interocellar ; ocellocular space half the interocellar and equal to the front ocellar space ; vertex shallowly and closely punctate ; occiput slightly concave ; bristles as shown in the figure (Fig. 46). Viewed infront innerorbital border straight ; interorbital space uniform ; antennae inserted below the middle of the face, slightly above the imaginary line joining the lower margin of the innerorbital borders ; face below antennae light brown ; genal space one-third the innerorbital length ; face very finely and obscurely punctate and sparsely setose. Antennae (Fig. 48) scape pale white, rest of the antennal segments hyaline light brown ; segments eight ; scape, pedicel, ring-joint one, funicle four and club one ; scape thrice as long as broad, longer than the club and more than twice the pedicel ; pedicel shorter than the first segment of the funicle with a single stout bristle apically ; ring-joint very narrow ; funicular segments subequal, about twice as long as broad, linear sensoria not biserial ; club apparently biarticulate, slightly more than twice the preceding segment and ending in a nipple-like projection. Thorax black ; prothorax inconspicous hardly visible from above, narrower than the head ; mesothorax strongly rugulosely punctate anteriorly, the punctures not very well defined and virtually coalescent ; in the region of the scapulae shagreened ; parapsidal furrows complete ; scutellum and the axillae in the low power smooth and shiny but when viewed in high power they are minutely and shallowly punctate ; axillae large and contiguous ; propodeum except for the strongly marked median longitudinal carina smooth and shiny ; thorax with pretegular, prescutellar and

[1]Mani (1935). *Rec. Indian Mus.*, 37(3) : 256



Figs. 46-52. *Euplectrus maternus*, sp. nov. ♀
46. head infront, 47. wing, 48. antenna, 49. hindleg, 50. stigmal and postmarginal veins, 51. hindwing,
52. *Euplectrus maternus*, sp. nov. ♂ genitalia.

lateral bristles ; mesopleurae sparesely punctate with the femoral impression well marked. Wings hyaline, submarginal entire, postmarginal twice as long as the stigmal ; rest of the wing as in (Figs. 47, and 50). Legs-all the three legs including their coxae white ; hindcoxae smooth ; hind tibia with two very long, unequal apical spurs ; the longer less than twice the metatarsus and the shorter less than the two basal segments (Fig. 49). Abdomen mostly white except for a discontinuous centrally interrupted pale brown band apically ; laterally and at the extreme base brown ; petiole dark brown, about one-fourth the hindcoxa ; ovipositor concealed.

♂ Length 1·2 mm. Very similar to ♀ except smaller in size. Male genitalia Fig. 52.

Holotype 1♀ Parasitic on larvae of *O. materna* and *O. fullonia* Kanpur (U. P.) P. L. Chaturvedi. 9.viii.1947.

Allotype 1♂ Register number 14.

Paratypes 5♀♀ in spirit and 1♀ on slide, 1♂ on slide.

KEY TO species[1]

I. All legs, including their coxae, coloured yellow or white uniformly :

a. Pedicel armed with pairs of long, stout, bristles both basally and apically ; legs yellow...*E. ceylonensis* Howard.

b. Pedicel with two spines subapically....................................*E. plecopterae* Mani.

c. Pedicel with a single bristle towards the apex............................ *E. maternus*, sp. nov.

d. Pedicel unarmed, without bristles :

(i) Scutellum punctate, posterior ocelli placed near the margin of the eyes, pubescence whitish...*E. leucostomus* Rohwer.

(ii) Scutellum finely umbilicately punctate in the middle, posterior ocelli placed at a distance from the margin of the eyes, pubescence brownish ....*E. euplexiae* Rohwer.

II. Legs differently coloured ; black, brown, reddish-brown, light brown or a combination of these :

a. Pedicel shorter than the first segment of the funicle :

(i) Scape white, segments of funicle unequal ; hind coxa uniformly coloured black...*E. bussyi* Crawford.

(ii) Scape white, hind coxa brown basally, light brown apically. *E. mathuri*, sp. nov.

[1]Key to species by Mani (1935) *Rec. Indian Mus.*, 37(3) : 256 revised and modified so as to include the newly discovered forms.

(iii) Scape brown, segment of the funicle subequal; hind coxa black basally and reddish-brown apically........................*E. himalayaensis* Mani.

b. Pedicel as long as the first segment of the funicle :

(i) Scutellum basally indistinctly reticulate..............................*E. nyctemerae* Crawford.

(ii) Scutellum finely reticulo-lineate in front and polished behind............ *E. gopimohani* Mani.

c. Pedicel longer than the first segment of the funicle........................ *E. spodopterae*, sp. nov.

Family TETRASTICHIDAE

Tetrastichus lasiopterae, sp. nov.

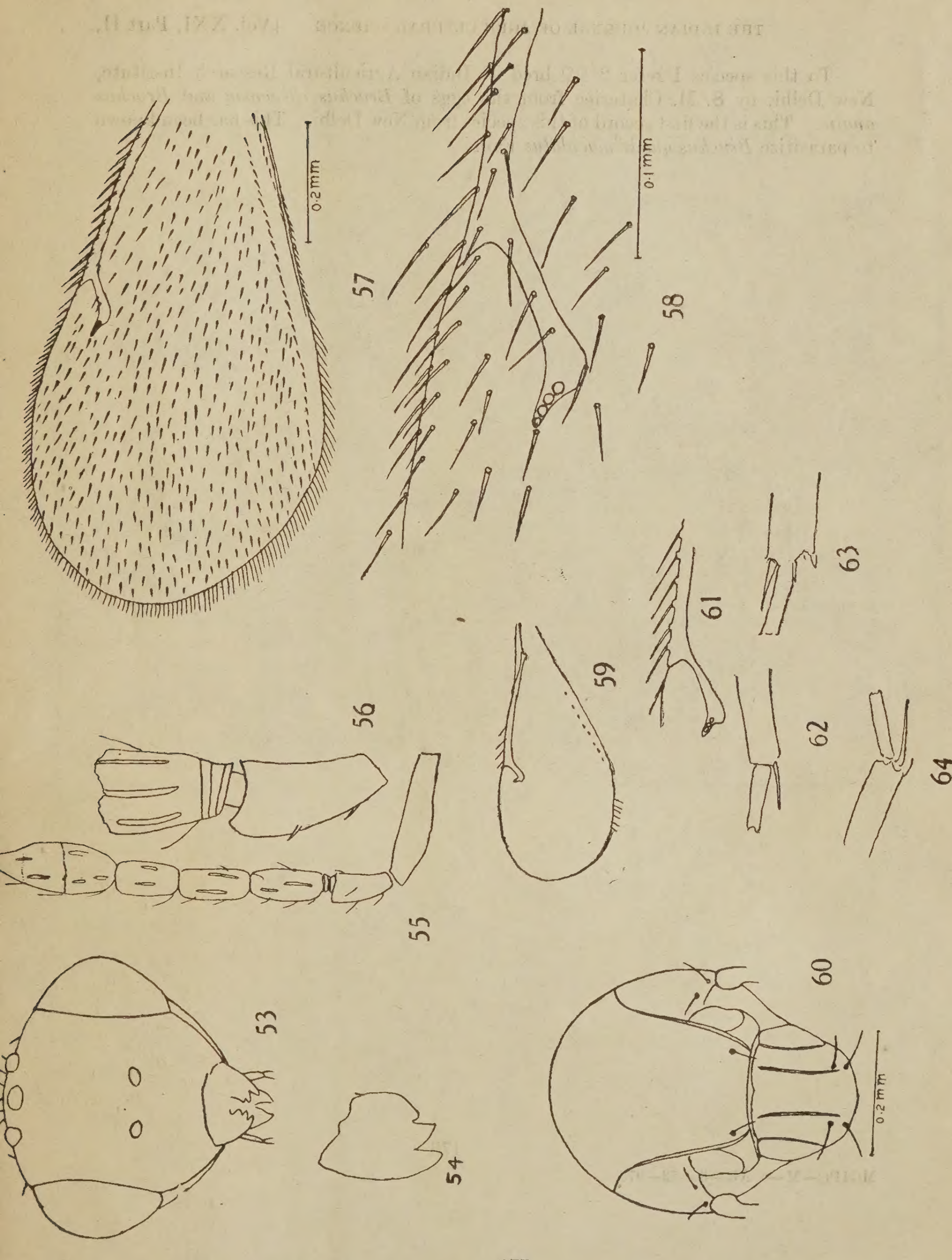
♀ Length 1·7 mm. Light brownish-yellow. Head. The vertex with a few scattered villous setae; more or less smooth; ocelli in a triangle, the interocellar space about equal to the ocellocular space. Viewed infront (Fig. 53) broader than high; antennae inserted slightly below the middle of the face and the inner orbital border; the distance between the antennal sockets equal to the distance between the eyes and the sockets; face virtually impunctate; genal space three-fifths the innerorbital length; eyes devoid of pubescence; two dark brown spots below the front ocellus which are very distinct when the head is viewed infront. Mandibles tridentate; first two teeth acute (Fig. 54). Antennae with nine segments; funicle three, ring-joints two and club two; scape four times as long as broad, cylindrical and equal to the club; pedicel twice as long as broad; ring-joints very short and narrow; first segment of the funicle about half the scape and slightly longer than the last segment of the funicle, longer than thick; club biarticulate with the indications of the third segment; one and half times as long as the last segment of the funicle; ending in a nipple-like projection (Fig. 55). Thorax light reddish-brown, slightly broader than the head; prothorax narrow and rectangular when viewed from above; mesothorax smooth with well marked and complete parapsidal furrows; scutellum entirely smooth with four longitudinal bands (Fig. 60); propodeum smooth; tegulae coloured as the mesothorax. Legs (Figs. 62, 63 and 64) light yellowish-brown; the hind tibial spur single and three-fourths the metatarsus; tarsi four jointed. Wing (Figs. 57, 58, 59 and 61) hyaline, the veins light yellow; submarginal approximately equal to the marginal; marginal with thirteen long setae distributed along its margin; postmarginal absent; stigmal slender about one-fourth the marginal discal ciliation moderate; marginal fringe dense. Abdomen sessile; longer than the thorax; tapering towards the apex; ovipositor subexserted.

Holotype 1♀ mounted on a slide. Register number 5B. Parasitic on Gall Midge larvae *Lasioptera falcata* Felt, Trivandrum (Travancore). K. K. Nayar. 11.viii.1947.

Family TRICHOGRAMMIDAE

Chaetostricha mukerjii, Mani

Mani (1935). *Chaetostricha mukerjii, Rec. Indian Mus.*, 37: 337
Mani (1938). *Chaetostricha mukerjii, Cat. Indian Ins.*, 23 : 140
Pruthi and Mani, *Chaetostricha mukerjii, ICAR Misc. Bull.*, 30 : 32



FIGS. 53-64. *Tetrastichus lasiopterae*, sp. nov. ♀
53. head infront, 54. mandible, 55. antenna, 56. ring-joints & pedicel, 57. wing, 58. stigmal vein. 59. wing, 60. thorax from above, 61. marginal vein, 62. foretibia with spur, 63. midtibia with apical spur, 64. hindtibia with the apical spur.

To this species I refer 2 ♀♀ bred at Indian Agricultural Research Institute, New Delhi, by S. M. Chateriee from the eggs of *Bruchus chinensis* and *Bruchus analis*. This is the first record of this species from New Delhi. This has been known to parasitize *Bruchus quadrimaculatus* Fabr.

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